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The present summary for 1908 is based essentially upon data received from about 200 regular Weather Bureau stations, 33 regular Canadian stations, and from such climatological stations as have forwarded their annual summaries in time. The statistical tables and charts have been prepared under the supervision of Prof. F. H. Bigelow, in charge of the Climatological Division, and the summary of flood movements by Dr. H. C Frankenfield, Professor of Meteorology.

FORECAST DIVISION.

Prof. E. B. GARRIOTT, in charge.

WEEKLY WEATHER FORECASTS.

By Prof. E. B. GARRIOTT.

In reply to numerous inquiries regarding methods employed in the preparation of weekly weather forecasts, answer has been made that they are based upon a consideration of atmospheric pressure over the oceans and continents of the Northern Hemisphere. Details of the calculations, that rest largely upon knowledge acquired by study and experience, can not, of course, be readily furnished. In a general way, however, it may be stated that the dependence of local weather changes upon world-wide atmospheric conditions has long been recognized, and careful studies of the relation and association of the great oceanic and continental barometric areas with marked types of weather have been made. In previous years studies of this character have necessarily been made with reports received by mail. During the past year daily telegraphic reports from selected stations thruout the Northern Hemisphere have permitted an application of the knowledge derived from these studies.

In the balancing of air masses over the Northern Hemisphere is found a cause of normal and abnormal weather in various portions of the hemisphere. In winter the greater masses, which are represented by areas of high barometric pressure, occupy the continents, and in summer the oceans are the seats of the so-called permanent areas of high barometer. In the shifting of the areas is produced what may be termed an annual ebb and flow of atmospheric tides; the air currents, or prevailing winds that attend the tides, are important factors in climatic changes and conditions. Marked departures from a normal distribution of air pressure result in decided departures from seasonal weather. In the relation of normal and abnormal pressure distribution to seasonable and unseasonable weather is found the problem of forecasting for periods of one to two weeks in advance. Generally speaking the distribution of pressure that is peculiar to a certain season will produce in a modified degree the weather of that season irrespective of the time of year.

The character of the barometric distribution over the Pacific Ocean and the continent of Asia indicates the development or approach of storms and high-pressure areas that will appear on the western coasts of the North American Continent; and barometric conditions over the Atlantic Ocean and Europe indicate the direction and speed of the movements over the American Continent. Marked departures in the Asiatic area indicate the general character of the weather of the United States for a period of about two weeks in advance; and Pacific pressure conditions and changes furnish a key to weather changes that will occur on the Pacific coast of the United States three or four days in advance and indicate the character of those that will occur over the eastern portion of the United States six to seven days in advance. The strength or magnitude of the storms, cold and warm waves, and other meteorological phenomena bear a relation to the departures from the normal pressure that appear over the oceanic and continental areas referred to.

The next advance in the forecast period will be achieved when the cause of unseasonable and unusual barometric pressures over the oceans and continents is known. If, as has been suggested, such abnormalities are due to variations in the solar radiations, the fact may be discovered when appliances for measuring the variations, if any exist, are perfected. In the meantime observed conditions and changes in world-wide pressures must form a base of operation, and facts, not theories, must be employed by the forecaster.

RIVERS AND FLOODS.

By Prof. H. C. FRANKENFIELD.

The floods of the year have been described in the various monthly issues of the MONTHLY WEATHER REVIEW. In these it can be seen that the forecast work in connection with the floods maintained its previous high character, and no flood of consequence was unheralded.

The scheme of river-stage forecasting for the Ohio River has been completed as far Louisville, Ky., and it is hoped to complete the scheme for the entire river during the year 1909.

Changes in administrative work are shown in the following summary:

NEW RIVER DISTRICT CENTERS.

Bismarck, N. Dak., with territory comprising the watershed of the Missouri River at and above Bismarck, N. Dak.

Wichita, Kans., with territory comprising that portion of the watershed of the Arkansas River from the Kansas-Colorado line to Wichita, Kans.

The territory of the Bismarck district was formerly a portion of the Sioux City, Iowa, district.

SPECIAL RIVER STATIONS OPENED DURING THE YEAR.

Station.	*District.*
Beaver Falls, Pa	Pittsburg, Pa.
Bellota, Cal	Sacramento, Cal.
Brazos, Tex	Galveston, Tex.
Bridgeport, Texas	Galveston, Tex.
Chamberlain, S. Dak	Sioux City, Iowa.
Cochran, Ariz	Phoenix, Ariz.
Edinburg, Miss	Meridian, Miss.
Elliston, Ind	Cairo, Ill.
Emporia, Kans	Fort Smith, Ark.
Espanola, N. Mex	Denver, Colo.
Estacada, Oreg	Portland, Oreg.
Fort Lyons, Colo	Denver, Colo.
Glendive, Mont	Bismarck. N. Dak.
Grand Junction, Colo	Denver, Colo.
Grand Reservoir, Ohio	Columbus, Ohio.
Hawkinsville, Ga	Macon, Ga.
Le Roy, Kans	Fort Smith, Ark.
Lewis Ferry, Tex. (P. O., New Boston.)	Shreveport, La.
Lewiston Reservoir, Ohio	Columbus, Ohio.
Licking Reservoir, Ohio	Columbus, Ohio.

SPECIAL RIVER STATIONS OPENED—continued.

Station.	District.
Lumber City, Ga	Macon, Ga.
Marble Falls, Tex	Galveston, Tex.
Medora, N. Dak	Bismarck, N. Dak.
Muscoda, Wis	Bubuque, Iowa.
New Martinsville, W. Va	Parkersburg, W. Va.
New River, Tenn	Nashville, Tenn.
Oxford Farmers Ditch, Colo	Denver, Colo.
Running Water, S. Dak	Sioux City, Iowa.
Shoals, Ind	Cairo, Ill.
Sistersville, W. Va	Parkersburg, W. Va.
Waterville, Pa	Harrisburg, Pa.
Williamsburg, Ky	Nashville, Tenn.

SPECIAL RIVER STATIONS CLOSED DURING THE YEAR.

Station.	District.
Barton, Oreg	Portland, Oreg.
Cedar Run, Pa	Harrisburg, Pa.
Edisto, S. C	Columbia, S. C.
Elko, Nev	Reno, Nev.
Ellwood Junction, Pa	Pittsburg, Pa.
Empire, Nev	Reno, Nev.
Floriston, Cal	Reno, Nev.
Gardnerville, Nev	Reno, Nev.
Halleck, Nev	Reno, Nev.
Ivanhoe, Va	Cincinnati, Ohio.
* Kiomache, Tex	Shreveport, La.
Las Animas, Colo	Denver, Colo.
Lovelocks, Nev	Reno, Nev.
Luxora, Ark	Memphis, Tenn.
Maricopa, P. and S. R., R. R. bridge, Ariz	Phoenix, Ariz.
Rogers, Ind	Cairo, Ill.
Rousseau, S. Dak	Sioux City, Iowa.
Sinnemahoning, Pa	Harrisburg, Pa.
Tahoe City, Cal	Reno, Nev.
Woodford, Cal	Reno, Nev.
Yerrington, Nev	Reno, Nev.

RIVER STATION REOPENED.

Station.	District.
Riparia, Wash	Portland, Oreg.

CHANGED FROM RAINFALL TO RIVER STATION.

Station.	District.
Youngstown, Ohio	Pittsburg, Pa.

RAINFALL STATIONS OPENED DURING THE YEAR.

Station.	District.
Albany, Tex	Galveston, Tex.
* Ansonia, Pa	Harrisburg, Pa.
Big Springs, Tex	Galveston, Tex.
Bowie, Tex	Galveston, Tex.
Brownwood, Tex	Galveston, Tex.
Colorado, Tex	Galveston, Tex.
Dublin, Tex	Galveston, Tex.
* Elizabeth, W. Va	Parkersburg, W. Va.
Gainesville, Tex	Galveston, Tex.
Graham, Tex	Galveston, Tex.
Greenville, Tex	Galveston, Tex.
Kerrville, Tex	Galveston, Tex.
Longview, Tex	Galveston, Tex.
Luling, Tex	Galveston, Tex.
Oslo, Minn	Moorhead, Minn.
San Angelo, Tex	Galveston, Tex.
San Marcos, Tex	Galveston, Tex.
Seymour, Tex	Galveston, Tex.
Weatherford, Tex	Galveston, Tex.

RAINFALL STATIONS CLOSED DURING THE YEAR.

Station.	District.
Battleboro, N. C	Raleigh, N. C.
Corona, Colo	Denver, Colo.
* Letohatchie, Ala	Montgomery, Ala.
Rockfish, Va	Richmond, Va.
Summit, Cal	Sacramento, Cal.
Tupelo, Miss	Mobile, Ala.

*Cooperative.

The highest and lowest river stages during the year at selected stations are given in Table IV.

SPECIAL ARTICLES, NOTES, AND EXTRACTS.

ATMOSPHERIC INFLUENCES CAUSING MOVEMENTS OF THE SOIL.

The records made by seismographs show that in general the superficial layer of gravel, clay, sand, or other form of loose soil resulting from the disintegration of solid rock is subject to a variety of movements that have no connection with earthquakes properly so-called.

Among these microseismic movements many have a meteorological origin; such are the slow tiltings due to the infiltration of rain water, the freezing of the ground, the pressure of the wind against the walls of the buildings, the changes of atmospheric pressure and resulting changes in the weight of the superincumbent atmosphere, the added weight of a mass of freshly fallen rain or snow, the melting of glaciers and the diminished load on the continent, the changes in level and consequently in the weight and pressure of large interior lakes, the analogous changes in the level and pressure of the ocean water on the seacoasts due to winds and tides.

There are other movements due to strains in the solid rocky substratum or to the relief from strain; these belong to vulcanology and astronomy, and are traceable back to luni-solar tidal strains, to strains due to changes in the rotation of the globe, to volcanic heat and chemical changes, to the changes of aggregation that take place when amorphous strata slowly crystallize under pressure.

The slow tiltings or long tides that are so evident in every seismogram are frequently spoken of as due to the varying load of air, rain, or snow, acting on the solid rocky shell of our globe; but to me it seems more likely that these tiltings may be due to the influence of changes of load on our superficial soil, 5, 10, or 50 feet in depth, resting on a relatively rigid rocky soil. This soil is permeated with water and air. Like a sponge, it yields to every change of pressure. The water in deep wells, the water-tables, the flow of underground water, are usually found to vary with barometric pressure as plainly as they do with rainfall or melting snow, or freezing temperatures. The explanation of any local tilting phenomenon will not be satisfactory until we have thoroly studied the influence of atmospheric pressure on the soil and on the groundwater below the seismograph.

The study by Prof. Franklin H. King, of the Agricultural Experiment Station at Madison, Wis., on the behavior of groundwater shows how our seismographs are liable to be affected by changes of pressure and the reaction of the air below a wet soil.—*C. A.*

STUDIES ON THE PHENOMENA OF THE EVAPORATION OF WATER OVER LAKES AND RESERVOIRS.

By Prof. FRANK H. BIGELOW. Dated February 1, 1909.

IV.—THE PROGRESS OF THE RESEARCH IN 1908, AND THE PROPOSED CAMPAIGN FOR THE YEARS 1909 AND 1910.

(1) THE EXTENSION OF THE NUMBER OF STATIONS IN THE UNITED STATES.

In the year 1907 an examination of the Salton Sea, southern California, and its neighborhood, was made regarding its availability for an extensive research into the laws controlling the rate of evaporation of water in the open air over large lakes and reservoirs. A short series of observations, from August 1 to September 15, was made in that year at the city reservoir, Reno, Nev., on evaporation from pans located in different parts of the vapor blanket covering the reservoir. The object of this experiment was to determine the influence of the vapor blanket on evaporation. In the subsequent months, September, October, and November, 1907, a series of observations was made at Indio, Riverside County, Cal., about 15 miles north of the Salton Sea,[1] to discover what effect upon the evaporation would be caused by placing several pans in positions near each other, but differently located relatively to the ground, the set being entirely removed from a vapor blanket cover due to a water area. In 1908 the following series of observations were made: (1) July to December, at the Government date garden, Indio, Cal., two pans, one on the ground and one on a stand, 10 feet above the ground; (2) July to October, at the Government date garden, Mecca, Cal., two pans similarly located. Mecca is about one-half mile from the Salton Sea, and the vapor pressure is higher than at Indio or Reno, the mean daily vapor pressure at the dew-point being about 17 millimeters at Mecca, 12 millimeters at Indio, and 7 millimeters at Reno; (3) July, August, a row of pans set in a line perpendicular to the shore of the Salton Sea, extending from the shore into the desert about 1,500 feet, to determine the effect of the overhanging vapor blanket as it thins out in the surrounding dry atmosphere. Whatever results might be obtained in the extremely arid regions just mentioned, it was thought improbable that they could be transferred to the semiarid regions of the West, or to the humid regions of the Eastern and Southern States, without first taking a sufficient number of observations in different climates to check the formula thru this wide range of conditions.

A plan of cooperation was perfected between the United States Weather Bureau, the United States Reclamation Service, and the Water Resources Branch of the United States Geological Survey, by which simultaneous series of observations on the same schedule and plan should be taken at various places in the United States. The Weather Bureau furnishes the evaporation pans, thermometers, anemometers, burette gage tubes, record books, and computation tables, and the cooperating bureaus are to make the observations so far as practicable. Professor Bigelow paid a visit of inspection to the several stations mentioned below during the months July to October, 1908, in connection with his inspection of the climatological section centers of the United States Weather Bureau. At the several "projects" of the United States Reclamation Service it was generally proposed that a 2-pan station should be located immediately on a large water area, that a 2-pan station should be placed in the midst of an irrigated region, e. g., an alfalfa field, and that a 2-pan station should be placed in a dry area apart from natural water surfaces or irrigated ground. These three types of location characterize every irrigation project, and the law of evaporation must be studied under these three characteristic conditions. The following "projects" of the Reclamation Service will take part in the observation in 1909:

[1] See map in Monthly Weather Review, July, 1907, 35: Chart IX.

	Project.	Place.	County.	State.
1	North Platte.	Mitchell.	Scotts Bluff.	Nebraska.
2	Shoshone.	Powell.	Big Horn.	Wyoming.
3	Minidoka.	Rupert.	Lincoln.	Idaho.
4	Payette-Boise.	Boise.	Ada.	Idaho.
5	Umatilla.	Hermiston.	Umatilla.	Oregon.
6	Sunnyside.	North Takima.	Yakima.	Washington.
7	Klamath.	Klamath Falls.	Klamath.	Oregon.
8	Truckee-Carson.	Fallon.	Churchill,	Nevada.
9	Salt River.	Phoenix.	Maricopa.	Arizona.
10	Engle.	Engle.	Sierra.	New Mexico.
11	Carlsbad.	Carlsbad.	Eddy.	New Mexico.

Also the following reservoirs under the supervision of the United States Geological Survey:

	Reservoir.	Place.	County.	State.
12	Chicago Drainage Canal.	Lockport.	Will.	Illinois.
13	Cincinnati.	California.	Hamilton.	Ohio.
14	East Lake.	Birmingham.	Jefferson.	Alabama.
15	Tupper Lake.	Tupper Lake.	Franklin.	New York.

The following stations[1] are to be established on or near the Salton Sea, California:

	Station.	Place.	County.	State.
16	Salt Creek Trestle.	near Durmid.	Riverside.	California.
17	Mecca.	Mecca.	Riverside.	California.
18	Indio.	Indio.	Riverside.	California.
19	Mammoth.	Mammoth.	San Diego.	California.
20	Brawley.	Brawley.	San Diego.	California.

The number of pans to be under observation is not known exactly, but it will probably exceed one hundred. The plan is to set the entire system of evaporation observations in operation as soon as the milder weather of spring opens up the waters on the Rocky Mountain Plateau, and immediately following the completion of the heavy construction work at the Salton Sea. It is hoped that eventually we may secure a general formula embracing all the conditions involved. Some account of the development of the formula is given in this paper. A "Manual" of instructions for taking the observations and making the computations has been prepared for the use of observers. It contains a series of tables which greatly facilitate the required computations.

(2) ANALYSIS OF THE THEORY AND FORMULA USED IN DISCUSSING THE EVAPORATION OBSERVATIONS.

In calm weather, when the velocity of the wind is zero over a water surface, the columns of vapor which escape from the water in the process of evaporation may be analyzed as constituting a sheaf of tubes, which are concentrated at the water area, but gradually spread out under the lateral hydrostatic pressure and overlay the boundaries of the reservoir or lake in the higher levels. These vapor pressure tubes are illustrated in fig. 32.

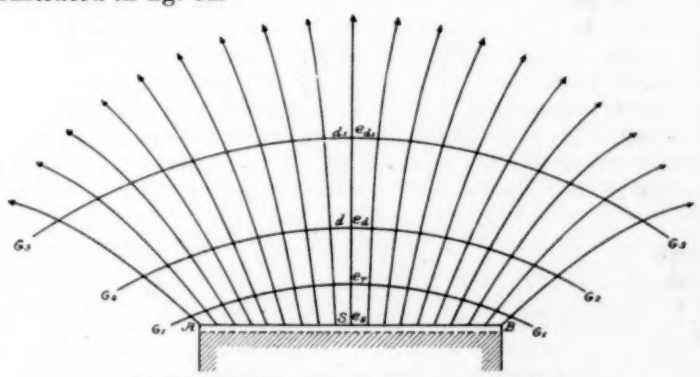


FIG. 32.—Evaporation from a water surface.

AB = the evaporating water surface.

G_1, G_2, G_3 = surfaces of equal vapor pressure.

e_s = vapor pressure of saturation at the temperature S.

e_r = vapor pressure at 1 cm. above the water surface.

e_d = vapor pressure at the dew-point temperature.

$\frac{e_s}{e_r}$, $\frac{e_s}{e_d}$, represent pressure gradients of the vapor escaping along the stream lines.

There is a longitudinal vapor pressure acting along these tubes, and another vapor pressure which acts at right angles to them. This hydrostatic pressure is maintained by a flow of the vapor particles in certain masses at a certain ratio along the tubes. A given volume of water can be turned into a definite volume of vapor at a given temperature, and the relations between the volume of water, v_2, and the corresponding volume of vapor, v_1, is exprest in Clapeyron's formula (18), MONTHLY WEATHER REVIEW, July, 1907, 35, p. 314. The rate at which this vapor moves along the tubes at any point depends upon the gradient of the vapor pressure actually existing at any cross section. This gradient is the resultant of a series of physical processes, which, perhaps, can not be fully exprest. These are the bombardment of the vapor molecules from the water surface toward the air, and of the air molecules toward the water. Whatever expression may be derived for the integral of such a double bombardment, the physical result is a certain vapor pressure at each plane or section of the tube. This vapor pressure varies from section to section along the tube, and is measured at the several sections by the ordinary methods of psychrometry. The vapor pressure begins at the foot of the tube with the maximum, which is the vapor pressure of saturation, at the temperature of the water surface S, and here called e_s. This vapor pressure diminishes quite abruptly near the water surface, and falls along the tube to its minimum, which is the vapor pressure at the dew-point temperature of the atmosphere within 1 or 2 feet of the water surface, and this is called e_d. Intermediate between these values of vapor pressure, e_s and e_d, occur other values of e, called e_r, and the rate of fall of the vapor pressure or its gradient per centimeter can be studied by measuring such values of e_r as lie between e_s and e_d.

Practically, a Centigrade thermometer with a glass jacket was floated, just submerged, in the water, and its temperature S is the argument for e_s in the Smithsonian Table No. 43.[1] On a small raft at the height of one centimeter above the water surface, a dry-bulb thermometer and a wet-bulb thermometer were floated, and from their readings the values e_r were computed. The values of e_d were determined by the sling psychrometer for a distance of one or two feet above the water surface. This method, employed at Reno, Nev., gave us numerous examples for studying the entire subject. When the weather is not calm, and the wind is blowing at w kilometers per hour, the effect is to break up these tubes, so that new ones are forming close to the water surface to be distorted, broken, carried away in the wind, and to be converted into the heterogenous mass of shattered tubes called roughly the vapor pressure at the dew point. These tubes may be conceived as forming all over a water area. In a wind the tubes on the windward side are carried forward to accumulate more or less thickly on the leeward side, where the vapor pressure should be greater. Hence, evaporation is more rapid on the windward side than on the leeward side of a water area. This complication, due to the wind, is called the wind effect, and it is expressed by the term,

$$A\ E_1\ w = 0.0175\ E_1\ w,$$

where E_1 is the evaporation in a calm. The constant coefficient, $A = 0.0175$, was determined at Reno, Nev., but it will be verified on the towers at the Salton Sea. For the present we have

$$E_w = E_1\ (1 + 0.0175\ w).$$

The most important purpose to keep in mind, during the search for an evaporation formula, is that it shall be simple in practice. Much of the success of the work depends upon the possibility of accomplishing this result. The following explanation of the theory of this research applies this principle, and a simple formula that will follow accurately the subtle and complex variations of the amount of evaporation, as illustrated by the observations already made, is greatly to be desired. The formula for calm weather divides itself into at least four parts, (1) a set of physical constants, (2) the time factor, (3) an expression for the mass of water evaporated, and (4) the gradient of the vapor pressure. As the first two terms give no special trouble in themselves, our attention may be fixed upon the last two terms, Mass and Gradient.

Mass. The Clapeyron formula is written,

$$v_1 - v_2 = \frac{r_2}{T} \cdot \frac{dT}{de} \times \frac{41855000 \times 760}{1013240}.$$

In this formula the notation signifies

v_1 = the volume of vapor.
v_2 = the volume of water.
r_2 = the latent heat of water at the temperature T.
T = $273 + S$ = the absolute temperature of the water surface.
$\frac{de}{dT} = \frac{de}{dS}$ = the rate of change of the vapor pressure in the saturated condition, with the temperature.
41855000 = the mechanical equivalent of heat in ergs.
760 = the pressure of one atmosphere in millimeters.
1013240 = the pressure of one atmosphere in dynes.

The ratios $\frac{r_2}{T}$ and $\frac{de}{dS}$ can be derived from ordinary physical tables and with the values of v_1 derived from $v_2 = 1$ cubic centimeter of water are shown in Table 23.

TABLE 23.– *Evaluation of the terms in Clapeyron's formula.*

T	r_2	$\frac{r_2}{T}$	$\frac{de}{dS}$	v_2	v_1
°					
273	606.5	2.22	0.330	1	211356
283	599.4	2.12	0.610	1	109006
293	592.3	2.02	1.075	1	59312
303	585.3	1.93	1.815	1	33507
⋮	⋮			⋮	⋮
373	535.7			1	1659

From this table we see that for ordinary atmospheric temperatures v_2 is relatively so small that it may be neglected in the expression $v_1 - v_2$. Furthermore, the ratio $\frac{r_2}{T}$ is nearly constant and may be assumed equal to 2 with little error for the atmospheric temperatures at which evaporation takes place vigorously, namely, from 10° to 30° C. It is evident that

$$dT = d(273 + S) = dS.$$

Transposing the Clapeyron formula, it thus becomes

$$\frac{de}{dS} = \frac{1}{v_1} \times \frac{2 \times 41855000 \times 760}{1013240} = \frac{1}{v_1} \times 62798.$$
$$= \rho_1 \times \text{constant}.$$
$$= \text{mass per unit volume} \times \text{constant}.$$

Hence, $\frac{de}{dS}$ is approximately proportional to the mass that passes thru the vapor tube from the surface of the water to the free air. The advantage of this expression for mass is that it is easily derived from the surface temperature, S, of the water surface as determined by the floating submerged thermometer. $\frac{de}{dS}$ is obtained from Smithsonian Meteorological Table 43 by subtracting the vapor pressure e for suc-

[1] Smithsonian meteorological tables. Third revised edition. Washington, 1907. Table 43, p. 142.

cessive degrees C. and taking the mean of the values for the observed temperatures S as the rate of change of the vapor pressure per degree. The rate of the evaporation at any temperature is proportional to this term $\frac{de}{dS}$, except so far as it is controlled by the passage of the vapor along a tube which contains a mixture of dry air and vapor gas. The flow of the vapor pressure in the tube is dependent upon the gradient, and this is measured by the vapor pressure from section to section.

Gradient.—It was thought that by measuring the vapor pressure at the water surface, e_s, and at a distance of one centimeter above it, e_r, some knowledge regarding this vapor pressure gradient might be obtained. As the result of several extensive computations on the Reno, Indio, and Mecca observations, it was decided to continue the research with the following evaporation formula,

$$E_o = C_d \times 0.100 \frac{e_s}{e_d} \cdot \frac{de}{dS}(1 + Aw).$$

It will be noted that the vapor pressure e_r does not appear in the formula, but that the vapor pressure at the dew-point temperature has taken its place. The computations were first conducted by means of the ratio $\frac{e_s}{e_r}$, but it was found that the ratio $\frac{e_s}{e_d}$ works equally well, tho of course the coefficient C_d has another value. For the Reno observations the value of the coefficient for 4-hour intervals is about 0.100 and the variations can be expressed in terms of a small coefficient, C_d, which is still to be determined. Since E_o is the observed evaporation and all the terms except C_d are found by direct instrumental observation, we have,

$$C_d = \frac{E_o}{0.100 \frac{e_s}{e_d} \cdot \frac{de}{dS}(1 + Aw)} = \frac{E_o}{E_1 + E_1 Aw} = \frac{E_o}{E_1 + E_2}.$$

A "Manual for Observers in Climatology and Evaporation" has been prepared in which are found tables for computation and examples, besides such descriptions as will make the procedure clearly understood by observers. Tables I and II are for computing e_d; Table III for e_s; Table V for $\frac{de}{dS}$; Table VI for E_1, and Table VII for E_2.

The equation

$$E_1 = 0.100 \frac{e_s}{e_d} \cdot \frac{de}{dS}$$

gives the evaporation in four hours under the temperature conditions of the atmosphere and the water in a calm; and $E_1 = E_0$ whenever $C_d = 1.00$.

The equation

$$E_2 = E_1 Aw = 0.100 \frac{e_s}{e_d} \cdot \frac{de}{dS} \times 0.0175\, w,$$

shows the effect of the wind on the amount evaporated in four hours. Since e_s and $\frac{de}{dS}$ are directly functions of S the term E_1 is found thru the arguments S and e_d; E_2 is computed thru the arguments E_1 and w. If the coefficient C_d were constant the formula would be simple and satisfactory, as will be shown. It seems to be a variable, and it is the next step in the research to discover its function. In thus assuming trial functions for one term after another, and discussing their capability to follow the observations made under numerous conditions of evaporation, we shall gradually approach the function which will be adopted for the entire phenomena in nature.

There are two reasons for employing the ratio $\frac{e_s}{e_d}$ in the formula instead of the ratio $\frac{e_s}{e_r}$. The sling psychrometer is preferred as an instrument to the floating raft psychrometer, and it is in the hands of all meteorologists. The dry-bulb thermometer on the raft is liable to get wet in rough water, and thus spoil the observation. The floating submerged thermometer and the sling psychrometer are not open to this criticism.

The ratio $\frac{e_s}{e_d}$ needs a word of comment. In the Dalton formula the difference $e_s - e_d$, may approach the value 0, and this would imply that evaporation ceases when $e_s = e_d$. It is, however, probable that even when $e_s = e_d$, and the vapor pressure in the air is the same as that at the water surface, there is a flow of vapor in the tubes required to maintain the vapor pressure e_d near the water. If the above ratio is used it may become $\frac{e_s}{e_d} = 1$ at the limit, but this will permit an evaporation represented by $\frac{de}{dS}$ to continue. It was shown at Reno that the evaporation continues vigorously during the night even when e_d is nearly equal to e_s. The product $\frac{e_s}{e_d} \cdot \frac{de}{dS}$ is so nearly proportional to the observed evaporation at Reno as to suggest that C_d is a constant. This is not really the case because C_d is different at the three stations, Mecca, Indio, and Reno, indicating that the true function requires a further modification of some kind. Illustrations of the working of the formula will be given, which tend to elucidate the phenomena of evaporation in the open air.

(3) EXAMPLES OF THE USE OF THE EVAPORATION FORMULA.

In the MONTHLY WEATHER REVIEW, February, 1908, **36**, p. 34–39, were given some examples of the action of Bigelow's first formula for the amount of evaporation observed at 3-hour intervals at Reno, Nev., August 1 to September 15, 1907. At that station five towers were erected at a double reservoir, and a series of pans were placed on each tower at 10-foot intervals extending from the water surface to 45 feet above it. The general result was that the C-coefficient had an interesting but large variation in the system, indicating that a satisfactory formula had not been secured. For the purpose of eliminating this variation, by introducing a different function for the vapor pressure relations, Bigelow's second formula was developed, and the account of it here given, while very brief, shows that the variation of the C-coefficient has been greatly reduced, tho it has not been fully accounted for by this formula, It is hoped that the campaign of 1909 will enable us to analyze the remaining variation, and thus complete the formula. The Dalton formula depends upon the difference of the vapor pressure, $e_s - e_d$, while Bigelow's first formula depended simply upon e_d, and the second upon the ratio e_s/e_d, as already explained, to express the gradient term. There was some doubt whether the ratio should be e_s/e_r or e_s/e_d, but it has been decided that the latter is the proper one to be used in practical work, In addition to illustrating the relations between the C_d-system, using the ratio e_s/e_d, and the C_r-system, using the ratio e_s/e_r, examples are given of the computations by following the formula strictly, and the corresponding computations by using the tables contained in the Manual for Observers in Climatology and Evaporation, to be issued by the Weather Bureau in 1909. These tables simplify the computation very much, and in connection with the Record Book supplied by the Weather Bureau to observers, make the computing as compact as possible, Crelle's multiplication tables are needed.

Computation by formula.

Table 24 illustrates the computation of the observations at Reno, Nev., tower 2, pan 1, August 12–17, 1907, by the formula

$$E_o = C_d \cdot \frac{e_s}{e_d} \cdot \frac{de}{dS}(1 + Aw).$$

In this table

$$C_d = \frac{E_o}{\frac{de}{dS} \cdot \frac{e_s}{e_d}(1 + Aw)}.$$

S = temperature of the water surface.
e_s = vapor pressure at the temperature S.
e_d = vapor pressure at the dew-point d.
w = mean velocity of the wind in kilometers per hour.
E_o = observed evaporation for three hours.
$\frac{de}{dS}$ = expression for the mass. (Use Manual Table V.)
$\frac{e_s}{e_d}$ = expression for the gradient. (Use Crelle's tables.)
$(1 + Aw)$ = Expression for the wind effect. $A = 0.0175$.
Product = the three preceding terms multiplied together.
Means = the mean values of the successive pairs on the line of products.
C_d = the coefficient which contains the thermodynamic constants, the time elapsed for the evaporation interval and some unknown function, e. g., diffusion.

TABLE 24.—*Examples of the computations by the formula,*

$$E_o = C_d \cdot \frac{e_s}{e_d} \cdot \frac{de}{dS}(1 + Aw).$$

Reno, Nevada, tower 2, pan 1, August 12–17, 1907.

Term.	A. M.				P. M.				Sum.	Means.
	2	5	8	11	2	5	8	11		
S	15.3	15.7	18.6	22.2	22.2	19.9	17.3	16.0	.....	18.4
e_s	12.9	13.3	15.9	19.9	19.9	17.3	14.7	13.5	.....	15.9
e_d	7.1	7.3	8.1	7.5	8.0	7.6	6.9	7.0	.....	7.4
w	12	7	3	9	13	25	23	17	.....	14
E_o	0.110	0.100	0.105	0.155	0.210	0.190	0.170	0.140	1.180	0.148
de/dS	0.83	0.85	1.00	1.21	1.21	1.07	0.93	0.86	.....	1.00
e_s/e_d	1.82	1.82	1.96	2.65	2.49	2.28	2.13	1.93	.....	2.14
$(1 + Aw)$	1.21	1.12	1.05	1.15	1.23	1.44	1.40	1.30	.....	1.24
$e_s/e_d \cdot de/dS$	1.51	1.55	1.96	3.21	3.01	2.44	1.98	1.66	.....	2.17
Product	1.83	1.73	2.06	3.69	3.70	3.51	2.77	2.16	21.45	2.68
Means	2.00	1.78	1.90	2.88	3.70	3.61	3.14	2.47	.....	.....
C_d	0.055	0.056	0.055	0.054	0.057	0.053	0.054	0.057	0.55	0.055

Computation by tables.

The same example, arranged for computing by the aid of the tables in the Manual, is shown in Table 25, where

$E_1 = 0.100 \cdot \frac{de}{dS} \cdot \frac{e_s}{e_d}$, = the evaporation in calm periods.
$E_2 = E_1 Aw$, = the wind effect.
$E = E_1 + E_2 = E_1(1 + Aw)$.
E_m = means of two successive values of E.
E_o = the observed evaporation in three hours.

TABLE 25.—*The same example arranged for computation by the tables.*

Term	A. M.				P. M.				Sum.	Means.
	2	5	8	11	2	5	8	11		
S	15.3	15.7	18.6	22.2	22.2	19.9	17.3	16.0	.....	18.4
e_d	7.1	7.3	8.1	7.5	8.0	7.6	6.9	7.0	.....	7.4
w	12	7	3	9	13	25	23	17	.....	14
E_1	0.15	0.15	0.20	0.32	0.30	0.24	0.20	0.17	.....	0.22
E_2	.03	.02	.01	.05	.07	.11	.08	.05	.....	.05
E	.18	.17	.21	.37	.37	.35	.28	.22	.....	.27
E_m	.200	.175	.190	.290	.370	.365	.315	.250	.....	.....
E_o	.110	.100	.105	.155	.210	.190	.170	.140	1.180	.148
$0.100\ C_d$	.055	.057	.055	.053	.057	.052	.054	.056	.055	.055

TABLE 26.—*The same example arranged for computation by the tables, but using e_r instead of e_d.*

Terms.	A. M.				P. M.				Sum.	Means.
	2	5	8	11	2	5	8	11		
S	15.3	15.7	18.6	22.2	22.2	19.9	17.3	16.0	.....	18.4
e_r	9.4	9.3	12.0	12.1	11.1	12.2	9.7	9.5	.....	10.7
w	12	7	3	9	13	25	23	17	.....	14
E_1	0.11	0.12	0.13	0.20	0.22	0.15	0.14	0.12	.....	0.15
E_2	.02	.01	.01	.03	.05	.07	.06	.04	.....	.04
E	0.130	0.130	0.140	0.230	0.270	0.220	0.200	0.160	.....	0.190
E_m	0.145	0.150	0.135	0.185	0.250	0.245	0.210	0.180	.....	.....
E_o	0.110	0.100	0.105	0.155	0.210	0.190	0.170	0.140	1.180	0.148
$0.100\ C_r$	0.076	0.077	0.078	0.084	0.084	0.078	0.081	0.078	0.079	0.078

These three examples of computation with the same data of observation are given for the sake of illustration the method of procedure. In Table 24 the computation is carried thru by means of Crelle's multiplications tables; in Table 25 it is per-

TABLE 27.—*Observations at Reno, Nev., August 12–17, 1907. Comparison of the computed coefficients C_d and C_r.*

Tower.	A. M.				P. M.				Means.
	2	5	8	11	2	5	8	11	
					C_d for Pan 1.				
Tower 2.	.055	.055	.056	.055	.060	.055	.055	.056	.056
Tower 3.....	.055	.054	.059	.057	.052	.056	.054	.060	.055
Tower 4.....	.055	.050	.051	.064	.059	.060	.061	.062	.058
Mean C_d.....	.055	.053	.055	.059	.057	.057	.057	.059	.056
					C_r for Pan 1.				
Tower 2.....	.076	.076	.078	.079	.084	.078	.081	.078	.079
Tower 3.....	.076	.076	.074	.076	.081	.073	.071	.072	.076
Tower 4.....	.067	.066	.068	.077	.077	.080	.073	.071	.072
Mean C_r.....	.073	.073	.073	.077	.081	.080	.075	.074	.076
					C_d for Pan 3.				
Tower 2.....	.062	.085	.074	.058	.071	.061	.059	.068	.069
Tower 3.....	.077	.083	.074	.055	.057	.062	.068	.070	.068
Tower 4.....	.072	.084	.087	.072	.064	.070	.071	.064	.073
Mean C_d.....	.070	.084	.078	.065	.064	.064	.066	.077	.070
					C_r for Pan 3.				
Tower 2.....	.085	.108	.105	.107	.100	.084	.087	.098	.097
Tower 3.....	.100	.105	.102	.085	.077	.074	.085	.090	.090
Tower 4.....	.086	.091	.100	.088	.080	.078	.077	.077	.085
Mean C_r.....	.090	.101	.102	.097	.086	.079	.082	.088	.091
					C_d for Pan 5.				
Tower 2	.056	.069	.069	.072	.070	.075	.067	.068	.068
Tower 3.....	.064	.076	.073	.065	.068	.073	.076	.072	.072
Tower 4.....	.073	.078	.077	.058	.063	.063	.079	.076	.071
Mean C_d.....	.064	.074	.073	.065	.067	.070	.074	.072	.070
					C_r for Pan 5.				
Tower 2.....	.081	.100	.102	.118	.105	.104	.093	.098	.100
Tower 3.....	.094	.098	.100	.088	.084	.095	.108	.093	.095
Tower 4.....	.088	.091	.103	.096	.104	.091	.102	.098	.097
Mean C_r.....	.088	.096	.102	.101	.097	.097	.101	.096	.097
					C_d for Pan 7.				
Tower 2.....	.062	.077	.073	.071	.074	.070	.061	.063	.069
Tower 3.....	.076	.075	.073	.058	.052	.066	.083	.072	.071
Tower 4.....	.069	.077	.063	.065	.068	.071	.073	.065	.069
Mean C_d	.069	.076	.070	.065	.065	.069	.072	.067	.070
					C_r for Pan 7.				
Tower 2.....	.091	.097	.104	.112	.115	.096	.095	.093	.100
Tower 3.....	.098	.106	.109	.086	.077	.093	.107	.091	.096
Tower 4.....	.103	.103	.092	.102	.098	.091	.094	.097	.098
Mean C_r.....	.097	.102	.102	.100	.097	.093	.099	.094	.098

formed by means of the tables in Bigelow's Manual; in Table 26 the system is changed from $\frac{e_s}{e_d}$ which gives C_d to $\frac{e_s}{e_r}$ which gives C_r. It is noted that the coefficients are nearly alike thruout the twenty-four hours, and this indicates that the diurnal variation of the evaporation has been eliminated. It will be shown that the variation of the evaporation between 10 and 45 feet above the water on the towers at Reno has also been eliminated by this formula. Unfortunately the C-coefficient is not constant from the water surface up to about 10 feet in height, nor is it constant from one climate to another. The probability is that the formula lacks one term. By substituting the vapor pressure e_r for e_d the computation for C_r shows that at Reno, Nev.,

$$\frac{C_r}{C_d} = \frac{0.079}{0.056} = 1\,41.$$

The purpose of a formula is to eliminate, (1) the diurnal variation at a given pan, (2) the vertical variation on a tower at a given place, (3) the horizontal variation over a given reservoir, (4) the general variation due to changes in latitude and longitude. These steps will be more fully illustrated by extracts from our computed results.

The irregularities in the above computed values of C_d and C_r can be referred to imperfections in the observations. It is noted that both systems tend to produce constants thruout the day, thus showing that the diurnal variation is eliminated. The ratios of C_r/C_d for the several pans are as follows: Pan (1), 1.36; pan (3), 1.30; pan (5), 1.39; pan (7), 1.40; the mean of which is 1.36. Similar results, obtained from the observations at Indio and Mecca, lead to the conclusion that the vapor pressure at the dew-point temperature e_d, as obtained by the sling psychrometer, can be substituted for the vapor pressure e_r, as found by the stationary psychrometer floating on the raft. This obviates the necessity of securing vapor pressures at fixt planes above a water surface within the limits of 2 or 3 feet, and the raft can be placed in very rough water without guarding the upper thermometers from wave washing, since only the reading of the submerged thermometer S is required. The arguments for Table VI of the Manual are S and e_d; those for Table VII of the Manual are E_i and w.

(4) THE DETERMINATION OF THE C_d-COEFFICIENT AT SEVERAL LOCALITIES.

It is important to establish the relations of the C_d-coefficient to bodies of water and to soils in various climates, with the hope of determining the form of the function that is concealed within it, in the symbol C_d. A series of examples from the observations will be summarized and the conclusions stated as they seem to be justified. It is not practicable to reproduce the original observations for S, the surface temperature; e_d, the vapor presssure of the dew-point; w, the wind velocity in kilometers per hour, and E_o, the observed evaporation for the interval; but only the computed C_d for several series of observations, *i. e.:*

1. Evaporation from a small *reservoir*, Reno, Nev.
2. Evaporation from an *irrigated field*, Indio and Mecca, Cal., at the Government Date Gardens.
3. Evaporation in a *dry place* at Indio, Cal.

These illustrate the phenomena which are encountered in the study of evaporation, all of which must be included in the functions exprest by the formula, if it is to be fully satisfactory.

It is seen that the value of C_d at Reno, Nev., for the pans 3, 5, and 7 on each of towers 2, 3, and 4 is about 0.070 in all cases; the same is true on towers 1 and 5. This shows that the formula eliminates that part of the vertical variation which was found to exist when using Bigelow's first formula, as was

TABLE 28.—*C_d-coefficient for August-September, 1907, at Reno, Nev. Evaporation from a small reservoir.*

TOWER 2.

Dates.	A. M. 2	A. M. 5	A. M. 8	A. M. 11	P. M. 2	P. M. 5	P. M. 8	P. M. 11	3-hour means.	4-hour means.
Pan 1, height 0 feet.										
August 1–10	.057	.053	.054	.060	.056	.055	.059	.056	.058	.....
12–17	.052	.054	.055	.055	.057	.053	.054	.053	.054	.....
19–24	.057	.056	.057	.059	.062	.063	.059	.056	.059	.....
26–31	.060	.061	.064	.064	.065	.063	.062	.060	.062	.....
September 2–7	.059	.058	.063	.064	.062	.060	.060	.064	.061	.....
9–14	.055	.055	.055	.061	.063	.059	.053	.055	.057	.....
Means	.057	.056	.058	.061	.061	.059	.058	.056	.056	.074
Pan 3, height 5 feet.										
August 1–10	.071	.074	.075	.075	.061	.056	.062	.071	.068	.....
12–17	.056	.077	.071	.068	.077	.065	.058	.064	.067	.....
19–24	.074	.081	.092	.082	.082	.068	.068	.072	.079	.....
26–31	.060	.074	.077	.072	.063	.057	.059	.056	.070	.....
September 2–7	.064	.068	.077	.077	.073	.058	.059	.066	.068	.....
9–14	.078	.073	.079	.083	.066	.062	.059	.078	.072	.....
Means	.067	.075	.079	.079	.070	.061	.061	.068	.071	.094
Pan 5, height 25 feet.										
August 1–10	.072	.075	.068	.075	.072	.071	.072	.071	.072	.....
12–17	.053	.068	.068	.068	.066	.073	.065	.065	.066	.....
19–24	.067	.071	.077	.066	.074	.068	.059	.060	.068	.....
26–31	.071	.069	.079	.080	.061	.056	.081	.071	.071	.....
September 2–7	.069	.072	.076	.077	.065	.056	.062	.061	.067	.....
9–14	.071	.074	.076	.078	.067	.052	.056	.072	.068	.....
Means	.067	.072	.074	.074	.068	.063	.064	.067	.069	.092
Pan 7, height 45 feet.										
August 1–10	.074	.074	.072	.071	.069	.071	.071	.074	.072	.....
12–17	.068	.083	.071	.064	.082	.076	.062	.057	.070	.....
19–24	.069	.066	.069	.069	.088	.083	.078	.074	.076	.....
26–31	.067	.071	.084	.075	.065	.055	.056	.066	.067	.....
September 2–7	.070	.067	.077	.076	.063	.054	.060	.062	.066	.....
9–14	.064	.072	.069	.073	.072	.070	.070	.071	.070	.....
Means	.069	.072	.074	.071	.073	.068	.066	.067	.070	.093

TOWER 3.

Dates.	A. M. 2	A. M. 5	A. M. 8	A. M. 11	P. M. 2	P. M. 5	P. M. 8	P. M. 11	3-hour means.	4-hour means.
Pan 1, height 0 feet.										
August 1–10	.058	.054	.053	.054	.059	.064	.066	.062	.059	.....
12–17	.055	.054	.059	.057	.052	.056	.054	.056	.057	.....
19–24	.054	.055	.060	.063	.063	.062	.065	.062	.061	.....
26–31	.053	.053	.065	.067	.062	.056	.049	.048	.057	.....
September 2–7	.058	.056	.069	.069	.059	.060	.064	.059	.062	.....
9–14	.054	.054	.057	.055	.056	.056	.056	.054	.055	.....
Means	.055	.054	.061	.061	.057	.059	.059	.057	.056	.074
Pan 3, height 5 feet.										
August 1–10	.075	.072	.077	.069	.065	.058	.060	.072	.069	.....
12–17	.071	.077	.074	.075	.065	.059	.066	.068	.069	.....
19–24	.072	.080	.082	.069	.062	.062	.069	.070	.071	.....
26–31	.066	.074	.082	.067	.056	.055	.060	.054	.064	.....
September 2–7	.059	.071	.071	.062	.069	.061	.061	.055	.064	.....
9–14	.066	.072	.079	.072	.066	.060	.067	.070	.069	.....
Means	.065	.074	.078	.069	.064	.059	.064	.065	.068	.090
Pan 5, height 25 feet.										
August 1–10	.070	.075	.076	.074	.078	.077	.065	.074	.074	.....
12–17	.071	.074	.072	.066	.067	.070	.075	.071	.071	.....
19–24	.072	.080	.079	.077	.069	.068	.068	.070	.073	.....
26–31	.076	.081	.083	.074	.069	.068	.075	.081	.076	.....
September 2–7	.073	.084	.081	.079	.068	.064	.061	.057	.071	.....
9–14	.071	.071	.074	.071	.073	.068	.070	.071	.071	.....
Means	.072	.078	.078	.074	.071	.069	.069	.071	.073	.097
Pan 7, height 45 feet.										
August 1–10	.076	.078	.068	.067	.077	.085	.071	.073	.076	
12–17	.071	.073	.074	.075	.060	.065	.080	.071	.071	
19–24	.071	.077	.073	.070	.066	.063	.072	.080	.072	
26–31	.077	.080	.075	.074	.067	.057	.065	.073	.071	
September 2–7	.072	.079	.078	.063	.077	.077	.059	.059	.071	
9–14	.066	.071	.079	.074	.066	.063	.074	.076	.071	
Means	.072	.076	.075	.071	.069	.068	.070	.072	.071	.096

TABLE 28.—*C_d-coefficient for August–September, 1907, Reno, Nev.*—Cont'd.

Dates.	A. M.				P. M.				3-hour means.	4-hour means.
	2	5	8	11	2	5	8	11		
TOWER 4.										
Pan 1, height 0 feet.										
August 1–10	.055	.054	.055	.056	.055	.056	.056	.057	.056	
12–17	.055	.050	.051	.064	.059	.060	.061	.062	.058	
19–24	.061	.053	.052	.051	.056	.064	.067	.061	.058	
26–31	.047	.047	.053	.057	.054	.055	.054	.051	.052	
September 2– 7	.055	.055	.065	.056	.058	.056	.062	.058	.058	
9–14	.058	.057	.058	.057	.059	.059	.061	.057	.058	
Means	.054	.052	.054	.055	.055	.056	.060	.056	.055	.073
Pan 3, height 5 feet.										
August 1–10	.071	.071	.074	.075	.074	.067	.065	.059	.070	
12–17	.077	.076	.083	.062	.060	.070	.071	.074	.072	
19–24	.072	.075	.075	.072	.064	.063	.064	.076	.070	
26–31	.066	.077	.063	.072	.076	.061	.059	.056	.066	
September 2– 7	.064	.072	.078	.075	.065	.064	.071	.064	.069	
9–14	.063	.066	.069	.075	.079	.066	.064	.062	.068	
Means	.069	.063	.074	.072	.070	.065	.066	.064	.069	.092
Pan 5, height 25 feet.										
August 1–10	.072	.074	.073	.061	.059	.063	.063	.065	.066	
12–17	.072	.077	.081	.061	.063	.063	.080	.076	.072	
19–24	.070	.077	.071	.063	.060	.068	.072	.069	.069	
26–31	.076	.079	.076	.059	.049	.056	.056	.056	.063	
September 2– 7	.073	.076	.071	.065	.055	.056	.066	.066	.066	
9–14	.064	.064	.080	.072	.060	.054	.065	.067	.066	
Means	.071	.075	.075	.064	.058	.060	.065	.067	.067	.089
Pan 7, height 45 feet.										
August 1–10	.068	.072	.069	.076	.071	.068	.060	.059	.068	
12–17	.071	.075	.064	.063	.066	.070	.071	.066	.069	
19–24	.067	.069	.069	.062	.068	.070	.079	.081	.071	
26–31	.078	.082	.072	.064	.059	.058	.063	.071	.068	
September 2– 7	.065	.076	.081	.076	.066	.062	.060	.065	.069	
9–14	.069	.071	.070	.074	.064	.060	.061	.066	.067	
Means	.070	.074	.071	.069	.066	.065	.066	.068	.066	.092

fully explained in the MONTHLY WEATHER REVIEW for February, 1908. On the other hand there is a decided drop in the value of C_d, from 0.070 to 0.056, in passing from pan 3 to pan 1, that is to the surface of the water in the reservoir. It follows that the evaporation at the surface of the water body is $\frac{0.055}{0.070} = 0.82$ of that at a few feet above the surface. This same difference appears on the two-pan stands at Indio and Mecca, where the upper pan is evaporating 1.27 times faster than the one at the surface, after having applied the other functions of the formula. It is not known what should cause these changes in the lower layer of air, as regards the rate of evaporation, but it will be proper to present the facts as they appear in the observations made at Indio and Mecca, south California.

Evaporation observations at Indio and Mecca.

In 1908 the Weather Bureau erected two stations at Indio and Mecca, Cal., in the grounds of the experimental date gardens in charge of the Bureau of Plant Industry, U. S. Department of Agriculture, thru the courtesy of Prof. W. T. Swingle and Prof. S. C. Mason. At each station there was placed a 10-foot stand, carrying a 24-inch pan 10 feet above the ground, together with an anemometer reading in kilometers. On the ground was placed a 72-inch pan, resting upon a solid frame-work of wood that held the bottom flat and horizontal. Regular observations were made at 2, 6, and 10 a. m., and at 2, 6, and 10 p. m., by Mr. A. Stumph, at Indio, from July 8 to November 4, 1908; and by Mr. J. L. Southerland, at Mecca, from July 10 to November 8, 1908. These date gardens are irrigated to a moderate amount and the ground is kept a little moist, tho not so wet as in an irrigated alfalfa field, such as that in which were made observations at Reno, Nev., in 1907. Furthermore, at Indio, Cal., near the Southern Pacific Railroad station, a series of observations on five pans were maintained by Dr. C. Abbe, jr., from October 7 to November 10, 1907, concerning which further remarks will be made in a later paragraph.

TABLE 29.—*Evaporation observations at Indio and Mecca, Cal., C_d-coefficient for July–December, 1908. Evaporation over an irrigated field.*

U. S. DATE GARDEN, INDIO, CAL., (Stumph).

Series.	Pan (1), on ground.							Pan (2), 10 feet above ground.						
	A. M.			P. M.			Means.	A. M.			P. M.			Means.
	2	6	10	2	6	10		2	6	10	2	6	10	
0–10 1	.052	.055	.054	.054	.054	.049	.053	.078	.075	.075	.069	.078	.074	.075
0–10 2	.056	.061	.056	.043	.042	.038	.049	.073	.088	.083	.081	.065	.060	.076
0–10 3	.057	.062	.045	.054	.044	.041	.050	.097	.088	.089	.088	.099	.099	.093
0–10 4	.041	.048	.059	.045	.051	.039	.047	.082	.074	.100	.066	.056	.085	.077
10–20 5	.029	.055	.078	.079	.047	.031	.054	.041	.073	.108	.130	.083	.045	.080
10–20 6	.055	.058	.046	.046	.056	.070	.055	.074	.071	.066	.088	.085	.096	.080
10–20 7	.066	.065	.035	.039	.039	.037	.047	.101	.077	.076	.092	.065	.087	.083
10–20 8	.049	.055	.046	.055	.050	.060	.052	.064	.079	.073	.086	.093	.079	.079
10–20 9	.063	.045	.048	.056	.063	.062	.056	.108	.092	.190	.111	.108	.107	.104

U. S. DATE GARDEN, MECCA, CAL., (Southerland).

0–10 1	.047	.052	.059	.064	.060	.049	.055	.066	.063	.089	.082	.092	.080	.079
0–10 2	.045	.051	.045	.041	.057	.045	.047	.080	.094	.095	.093	.092	.078	.089
0–10 3	.046	.051	.054	.056	.048	.042	.050	.074	.074	.079	.090	.079	.073	.078
0–10 4	.051	.058	.056	.052	.042	.042	.050	.105	.109	.085	.100	.100	.089	.098
10–20 5	.053	.057	.057	.051	.043	.052	.052	.088	.067	.088	.088	.078	.069	.080
10–20 6	.048	.045	.041	.045	.044	.049	.045	.082	.091	.090	.089	.081	.081	.086
10–20 7	.046	.049	.050	.046	.046	.046	.047	.071	.074	.081	.083	.082	.078	.078
10–20 8	.058	.053	.057	.048	.051	.046	.052	.074	.068	.075	.081	.081	.099	.080
10–20 9	.049	.049	.046	.040	.049	.046	.047	.058	.066	.064	.075	.085	.072	.070

TABLE 30.—*Examples of the 4-hourly amounts of evaporation, E_o, from which the above values of C_d have been computed.*

INDIO, DATE GARDEN.

Series.	Pan (1), on ground.							Pan (2), 10 feet above ground.						
	A. M.			P. M.			Total E_o	A. M.			P. M.			Total E_o
	2	6	10	2	6	10		2	6	10	2	6	10	
	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.
1	.145	.113	.153	.261	.273	.181	1.126	.200	.156	.243	.371	.460	.313	1.743
2	.125	.104	.164	.228	.263	.170	0.954	.163	.155	.242	.430	.420	.273	1.683
MECCA, DATE GARDEN.														
1	.141	.143	.181	.280	.312	.196	1.253	.200	.173	.285	.420	.493	.320	1.951
2	.160	.130	.146	.249	.300	.227	1.212	.220	.180	.244	.426	.467	.347	1.884

TABLE 31.—*Evaporation observations at Indio, Cal., October–November, 1907; in a very dry field.* (Abbe.)

Dates.	C_d-coefficient.							Evaporation = E_o						
	2 a. m.	6 a. m.	10 a. m.	2 p. m.	6 p. m.	10 p. m.	Means.	2 a. m.	6 a. m.	10 a. m.	2 p. m.	6 p. m.	10 p. m.	Totals.
PAN 1. 24-inch, buried to the rim in the sand.														
								Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.
October 7–11	.034	.032	.030	.031	.028	.029	.031	.120	.087	.093	.163	.187	.150	.800
12–16	.034	.030	.033	.038	.034	.037	.034	.090	.070	.090	.121	.116	.121	.608
17–21	.033	.034	.037	.027	.031	.032	.032	.066	.058	.069	.076	.096	.080	.445
22–26	.036	.031	.039	.026	.037	.022	.032	.068	.046	.066	.065	.103	.050	.398
27–31	.037	.035	.029	.026	.025	.033	.031	.074	.063	.060	.095	.101	.087	.480
November 1–5	.037	.034	.028	.022	.023	.032	.029	.102	.070	.069	.100	.116	.115	.572
6–10	.035	.033	.038	.023	.030	.040	.033	.082	.070	.077	.066	.101	.113	.509
Means	.035	.033	.033	.028	.030	.032	.032	.086	.066	.075	.098	.131	.102	.545
PAN 2. 22-inch, on platform, rim 10 inches above ground.														
October 7–11														
12–16	.038	.037	.032	.032	.024	.026	.032	.076	.063	.072	.121	.117	.094	.543
17–21	.026	.021	.021	.025	.037	.027	.026	.042	.028	.033	.073	.118	.061	.355
22–26	.033	.029	.031	.033	.028	.034	.031	.049	.034	.043	.081	.078	.069	.354
27–31	.039	.035	.034	.024	.029	.033	.032	.064	.044	.058	.094	.123	.085	.468
November 1–5	.034	.034	.021	.023	.026	.032	.028	.074	.050	.041	.115	.146	.111	.537
6–10	.032	.025	.031	.026	.027	.029	.028	.053	.035	.048	.067	.083	.066	.352
Means	.034	.030	.028	.027	.028	.030	.029	.060	.042	.049	.092	.111	.081	.435
PAN 3. 26-inch, on platform, rim 10 inches above ground.														
October 7–11	.031	.028	.030	.031	.029	.028	.030	.090	.058	.092	.185	.200	.136	.762
12–16	.034	.035	.032	.027	.027	.035	.032	.076	.065	.078	.103	.106	.105	.533
17–21	.032	.027	.030	.029	.038	.021	.029	.052	.034	.046	.079	.112	.044	.367
22–26	.034	.029	.033	.034	.032	.022	.031	.052	.034	.046	.079	.082	.044	.337
27–31	.039	.034	.024	.025	.031	.040	.032	.065	.043	.041	.085	.115	.095	.444
November 1–5	.031	.031	.030	.024	.026	.031	.029	.072	.047	.059	.109	.131	.100	.518
6–10	.028	.022	.028	.028	.031	.022	.027	.048	.031	.052	.079	.092	.052	.354
Means	.033	.029	.030	.028	.031	.029	.030	.065	.045	.059	.103	.120	.082	.475
PAN 4. 72-inch, on platform, rim 10 inches above ground.														
October 7–11	.029	.027	.028	.024	.021	.025	.026	.086	.060	.075	.117	.130	.116	.584
12–16	.034	.027	.031	.025	.026	.039	.030	.080	.052	.071	.087	.100	.117	.507
17–21	.022	.025	.026	.024	.033	.021	.025	.038	.035	.040	.063	.103	.052	.331
22–26	.028	.023	.027	.029	.030	.024	.027	.043	.029	.037	.064	.075	.047	.295
27–31	.032	.029	.032	.024	.030	.033	.030	.057	.038	.051	.074	.105	.080	.405
November 1–5	.031	.028	.029	.024	.025	.028	.028	.066	.043	.055	.095	.108	.080	.447
6–10	.029	.027	.032	.033	.025	.031	.028	.051	.041	.053	.081	.069	.068	.363
Means	.029	.027	.029	.026	.027	.029	.029	.060	.043	.055	.083	.099	.080	.419
PAN 5. 24-inch, on platform, rim 2 feet above the ground.														
October 7–11														
12–16	.035	.035	.032	.025	.035	.037	.033	.078	.066	.085	.108	.154	.114	.605
17–21	.026	.022	.029	.041	.036	.021	.029	.041	.027	.050	.135	.117	.050	.420
22–26	.026	.026	.025	.040	.029	.027	.029	.039	.036	.041	.082	.087	.058	.343
27–31	.040	.037	.026	.038	.029	.035	.034	.064	.045	.045	.161	.133	.088	.536
November 1–5	.040	.039	.021	.030	.023	.034	.031	.084	.056	.044	.168	.142	.113	.607
6–10	.024	.023	.028	.023	.030	.026	.026	.048	.032	.045	.069	.099	.066	.359
Means	.032	.030	.027	.033	.030	.030	.030	.059	.044	.052	.121	.122	.082	.478
Means	.033	.030	.029	.028	.029	.030	.030	.066	.048	.058	.099	.117	.085	.471

These values of E_o, the observed amount of evaporation in 4-hour intervals, are typical of the quantities from which C_d has been deduced by an inversion of these formula.

The observations at the Indio and Mecca date gardens, made by Stumph and Sutherland, were assorted at the time of the observing into three groups according to the wind velocities, so that they should fall into three sets according as the mean wind velocity for the producing four hours lay between the intervals 0–10, 10–20, 20–40 kilometers per hour, respectively (see Table 29, column 1). Since the wind velocity changes considerably in the course of the day, it frequently happens that the observations for the same date are entered under different wind groups. They were entered as they were thus assorted under the six observation hours until about ten observations were collected for the same pan at the same hour. The meteorological conditions were approximately the same from day to day in that climate and the ten observations were brought together in this computation of C_d. It is evident that while there is a test of value of the adopted coefficient, $A = 0.0175$, determined at Reno, Nev., this is, in some cases, at the expense of the uniformity of the C_d-coefficient in the course of the day. Table 29 contains the values of C_d for 9 series at Indio and for 9 series at Mecca, and they show that there is no important change of C_d with the velocity of the wind. Series 9 on Pan 2 at Indio is larger, but Series 5 on Pan 2 at Mecca is smaller, while the other variations in these series are such as may be expected. The mean values of C_d for Indio and Mecca, are:

Pan (1) on the ground, $C_d = 0.052$
Pan (2) about 10 feet above the ground, $C_d = 0.080$ } Ratio 1.54.

The similar data obtained at the dry place near the Southern Pacific Railway station, as given in Table 31, produces for the pans on the ground, $C_d = 0.030$. Reducing the values of C_d found at Reno, Nev., for the three-hour intervals to corresponding four-hour intervals by the factor 133, we find for—

Pan (1) on the water surface, $C_d = 0.098$
Pans (3), (5), (7) above the water, $C_d = 0.124$ } Ratio 1.27.

Collecting these results, we have for the several coefficients:

	Pan on surface.	Pan 5–10 feet higher.
Evaporation over a water surface,	$C_d = 0.098$	$C_d = 0.124$
Evaporation in an irrigated field,	$C_d = 0.052$	$C_d = 0.080$
Evaporation in a very dry place,	$C_d = 0.030$	$C_d =$ ——

These data constitute a very difficult problem in evaporation, according to this formula. After having eliminated the large diurnal variation, already illustrated in Paper III of this series, MONTHLY WEATHER REVIEW, February, 1908, as well as the variation which exists from 5 to 45 feet above the water of the Reno reservoir, there *yet remains in the layer of air next to the ground 5 to 10 feet thick*, a remarkable discontinuity in the values of this coefficient. Not only is the value of C_d larger at 10 feet above the surface than it is at the surface itself, but the coefficient increases from the dry place thru the moderatly irrigated field to the reservoir water surface. A diligent examination of all our available data, surface temperatures S, air temperatures t, and t_1, vapor pressure e_s and e_d, as well as e_r, fails to disclose any apparent connection between them. Had the coefficient C_d happened to be *constant* it would have meant that the adopted formula is satisfactory. As matters stand this variation in the C_d-coefficient in the lower layer of air and with the local climatic conditions seems to call for an extended research for the missing term. I have accordingly, with this end in view, organized the campaign for the year 1909 by placing two-pan stands 10 feet high at each station, and locating three types of stations, (1) over a water surface, (2) over an irrigated field, and (3) in a very dry place. As already stated the stations are extended to cover 16 points of the United States.

(5) VARIATIONS IN THE EVAPORATION AT THE SAME PLACE.

It has been stated that difference in the size of the pans is an important factor in the rate of the evaporation at the same place. To test this point, and at the same time to show the effect of the relation of the location of the pan near the ground to the amount of evaporation, was the purpose of the experiment by Dr. C. Abbe, jr., near the Indio railroad station. Five pans were employed, and they were placed close to each other on the ground or near it. They were, therefore, under the same wind influences for each pan and the same general climatic conditions. The previous work at Reno was designed to test the effect of the vapor blanket overlaying a water surface, upon the evaporation from pans placed in different parts of it. This work at Indio entirely eliminated the vapor blanket effect, and the wind effect so far as any differential results are concerned. The pans were of the same depth, 10 inches in all cases, and their diameters and positions relative to the sand that formed the ground at that point were as follows:

Pan (1), 24-inch, buried up to the rim in the sand.
Pan (2), 22-inch,
Pan (3), 26-inch,
Pan (4), 72-inch, } standing on a platform, the rims about 10 inches from the ground.
Pan (5), 24-inch, standing on a platform; the rim 2 feet from the surface of the sand.

The right-hand half of Table 31 gives the mean values of the evaporation for the five-day intervals noted in the first column, as observed every four hours. A few interpolations at night were made by separating some eight-hour intervals into two four-hour intervals, 10 p. m.–2 a. m., and 2 a. m.–6 a. m., but the totals for the day are the same, and this is the only important consideration in this connection. The totals are given in the last column, and the means are taken for the entire interval, October 7 to November 10, 1908.

It is noticed that the C_d-coefficient, as given to the left hand half of Table 31, seems to be very consistent for the series thruout the day and for the five pans, as might be expected, since they stand in a dry place on nearly the same level. The general result is that the total daily amount of the evaporation at the several pans averages,

Pan (1), 24-inch, buried to the rim in the ground, 0.545 cm.
Pan (2), 22-inch, standing on the ground, 0.435 cm.
Pan (3), 26-inch, standing on the ground, 0.475 cm.
Pan (4), 72-inch, standing on the ground, 0.419 cm.
Pan (5), 24 inch, raised in the air above ground, 0.478 cm.

These two remarkable features are that the 24-inch pan buried in the ground loses 0.545 centimeters per day, and the 72-inch pan standing on the ground loses 0.419 centimeters per day. The 72-inch pan on the ground loses only 77 per cent of the 24-inch buried pan. The pans were placed so that the four small pans touched the large 6-foot pan as it were at points 90 degrees apart, except for the differences in the elevation. It has been the custom to bury pans in the ground, but it is here shown how different results can be obtained under the same meteorological conditions by such a difference of position. In order to exhibit the primary cause of this variation in the amount of the evaporation it is only necessary to bring together the mean surface temperatures for the five pans during the interval, October 7–November 10, 1907, at each of the six hours of the observations.

TABLE 32.—*Relation between water surface temperature S and E_o.*

Pans.	2 a. m.[2]	6 a. m.	10 a. m.	2 p. m.	6 p. m.	10 p. m.	Means.	E_o
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	Cm.
(1)	19.9	18.7	22.3	26.8	25.1	22.4	22.5	0.545
(2)	17.6	15.8	21.1	26.5	24.1	20.2	20.9	0.435
(3)	17.9	16.0	21.9	26.5	24.3	20.7	21.2	0.475
(4)	17.6	15.2	21.0	25.6	24.0	20.6	20.7	0.419
(5)	18.0	16.1	22.7	27.9	24.9	20.7	21.7	0.478

[2] Interpolated values.—*C. A., jr.*

It is evident that the sequences in the temperatures S of the water surface and in the amount of evaporation E_o are parallel and in a nearly equal proportion. The inference is that whatever caused the change in the temperature of the water thereby directly influenced the evaporation. By plotting the temperatures S it is seen that for pan (1) the temperature remained higher than the others during the night because, being buried in the sand, it was kept warmer by the continuous conduction of heat from the ground which, at the depth of 10 inches, cooled slower than the air above it. Pan (5), located 2 feet above the surface and surrounded by the free air, went to a higher temperature at its maximum about 2 p. m. than did the other pans, but it cooled off quicker than did pan (1). Pan (4), 6 feet in diameter, was the coolest of all for the entire day, and it is supposed to have acted somewhat like an umbrella to the ground underneath it and so have remained relatively less heated as a whole. These examples show the extreme difficulty, if not impossibility, of transferring the results of the evaporation in pans from one point to another. It is only safe to measure the temperature of the water surface *in situ*, and we shall adhere to this principle thruout the remainder of the research.

We have shown that the following terms enter vitally into an evaporation formula:

S, water surface temperature, centigrade.
t, dry-bulb temperature of the air, centigrade.
t_1, wet-bulb temperature of the air, centigrade.
w, wind velocity, in kilometers per hour.

Besides these, there are apparently some unknown terms concealed in the C_d-coefficient. This may involve certain very difficult physical processes, like diffusion and mixture of gases.

(6) THE PRACTICAL APPLICATION OF THE EVAPORATION FORMULA.

Mr. C. E. Grunsky expressed the view in Engineering News, Vol. 60, No. 7, August 13, 1908, that a formula of the above class, involving several variables, will fail to meet the requirement of the ordinary engineer, because he will not have before him the observational data needed for its evaluation. It is necessary to infer from the results collected in this series of papers that not only will the complete solution of the problem be difficult in itself, but also that the integration of the amount of the evaporation over a large body of water in a variable climate, especially where precipitation occurs irregularly, is a task of unusual difficulty. Until a final broad formula is secured, it is merely a matter of speculation to conjecture how much it can be simplified in practice. It is very possible that the average monthly amount of evaporation can be computed approximately from the mean monthly values of the meteorological elements. We can here show how the average daily evaporation can be computed from the mean daily meteorological values, as given above, provided the C_d-coefficient is known. Without that factor, the computation fails. But this coefficient can evidently be secured from a very few days of actual observing at a given locality, and then it can be applied to the meteorological data. Indeed, it is not too much to say that, having the C_d-coefficient, the amount of evaporation can be followed more accurately from the metoorological data than from the measurements in pans, subject to all sorts of disturbing conditions. The following table will show how to abbreviate the daily work of observing and computing, as assisted by Bigelow's Manual for Observers in Climatology and Evaporation, Weather Bureau, Washington, 1909.

TABLE 33.—*Abbreviation of the computation by using the mean daily values.*
Example from Table 25.

	A. M.				P. M.				Total. E_o	Daily means.	$\frac{5a+2p}{2}$
	2	5	8	11	2	5	8	11			
									Cm.		
S	15.3	15.7	18.6	22.2	22.2	19.9	17.3	16.0	.....	18.4	19.0
e_d	7.1	7.3	8.1	7.5	8.0	7.6	6.9	7.0	... ...	7.4	7.7
w	12	7	3	9	13	25	23	17	.....	14	14
E_1	0.15	0.15	0.20	0.32	0.30	0.24	0.20	0.17	.....	0.21	0.22
E_2	.03	.02	.01	.05	.07	.11	.08	.05	.....	.05	.05
E	.18	.17	.21	.37	.37	.35	.28	.22	.....	.26	.27
E_m	.200	.175	.190	.290	.370	.365	.315	.250	.....	2.08	2.16
E_o	.110	.100	.105	.155	.210	.190	.170	.140	1.180	1.144	1.188
0.100 C_d	.055	.057	.055	.053	.057	.052	.054	.056	.....	.....	.....

Mean 0.100 C_d = 0.055.

S, observe the water temperature for a series of hours.
e_d, observe t and t_1, dry and wet-bulb air temperatures.
w, read the anemometer and compute the average velocity per hour.
E_1, E_2, Manual Tables VI and VII. $E = E_1 + E_2$. E_m = means of pairs.
E_o, observed evaporation in 3-hour intervals.
C_d, $E_o / E_m = C_d$. Apply factor 0.100, due to the construction of the tables.

In the last column but one write down the mean values of S, e_d; from the data on the same line, adopt the same value of the w from the anemometer; compute E_1, E_2, E; multiply E by 8 for a time interval of twenty-four hours instead of three hours; multiply 2.08 by 0.055 and obtain 1.144 centimeters for the computed total evaporation for the day in place of 1.180 centimeters, as observed.

In the last column take the mean of the minimum and maximum values of S, e_d as observed at 5 a. m. and carry thru the computation to 1.188 centimeters. Now invert the process: Observe the total daily evaporation for twenty-four hours apart, as at 6 a. m., on two successive days. Observe the anemometer at two times twenty-four hours apart and divide the difference in the anemometer readings by 24 for w. Observe S, t, t_1 at about 6 a. m. and 3 p. m. Compute e_d at 6 a. m. and 3 p. m. Take the mean values of S and e_d. Compute E. Then $C_d = \frac{E_o}{8E}$.

In this way two observations at about 6 a. m. and 3 p. m. in summer, gradually contracting the time to 7 a. m. and 2 p. m. in winter, are capable of producing a very valuable result. It is desirable to have observations at 2, 6, and 10 a. m. and 2, 6, and 10 p. m., and at as many stations as possible, certainly at one station of each of the large reclamation projects. At the other stations on the same project, if it is not convenient to secure good observers to do the work for the complete set, six times daily, or five times, omitting the 2 a. m. observation. The hours of the observations can be limited to 6 a. m. and 3 p. m., these being near the minimum and maximum water temperatures. It is evidently necessary to find values for C_d in many localities in order to arrive at a general formula of evaporation applicable under all conditions.

THE CLIMATE OF THE HISTORIC PAST.

By ELLSWORTH HUNTINGTON. Dated New Haven, Conn., January 18, 1909.

[*Continued from the Monthly Weather Review for November, 1908.*]

PART II. THE NEW WORLD.

The climatic history of the New World appears to have been essentially the same as that of the Old World. The marked uniformity in the order of the main events of the glacial period on both sides of the Atlantic Ocean has led geologists to the conclusion that the Eastern and Western hemispheres were subjected to the various phases of this period at the same time. This conclusion is strengthened by the absence of any plausible theory upon which the phenomena of glaciation can be explained without an assumption involving such synchronism. In the Southern Hemisphere the glacial period produced the same succession of phenomena as in the Northern, but there is at present no general agreement as to whether a given phase, glacial or inter-glacial, occurred simultaneously or alternately, on both sides of the equator. On the whole, however, there seems to be a growing tendency toward the opinion that the events of the glacial period occurred simultaneously thruout the world.

Turning to the climate of modern time, it appears from the work of Brückner[1] and others that, altho there are certain oceanic and tropical regions of permanent exception, the continental regions of the earth as a whole pass almost simultaneously thru certain brief climatic cycles. Brückner's cycle of thirty-five or thirty-six years stands as the type of the changes in climate which are in progress at the present time. The dry phase of the cycle is marked by comparative aridity not only in North America and Eurasia outside the Tropics, but in similar continental regions of the Southern Hemisphere.

If it be true that glacial cycles and Brückner cycles affect all the continental regions of the Northern Hemisphere, and possibly of the whole world at once, it is probable that the intermediate cycles of which evidence is found in Asia affected the Western Hemisphere as well as the Eastern. There is distinct ground for believing this to be the case. Inasmuch as the historic period in the New World is far shorter than in the Old, there naturally is correspondingly less opportunity in the New to connect human events with any changes of climate of which evidence may be forthcoming. The American student is likely to turn first to Great Salt Lake to see if it has varied in size during the last two thousand years. Unfortunately the basin of the lake contains no ruins left by ancient man; and the known history of the region extends over only a century. Therefore, Great Salt Lake must be dismissed until further knowledge is obtained. It presents no known evidence either for or against a change of climate during historic times, altho it is well known that in the glacial period its size increased enormously.

The cliff-dwellings of the Zunis.—Altho North America presents no very strong evidence of climatic change, the Zuni ruins and the history of the city of Mexico deserve some discussion before the much stronger evidence in South America is described. South and southeast of Great Salt Lake the cliff-dwellings of the Zunis present a type of evidence comparable to that of the ruins of central Asia. Many dwellings, as is well known, are located in places where the supply of water seems utterly insufficient for the number of people who appear to have lived there. Students have attempted to explain this by supposing that the population at any one time was very small; they assumed that generation after generation went to the trouble of building new houses, leaving the old ones empty altho in perfect repair. An explanation of the apparent lack of water has been derived from the fact that in a few cases concealed springs have been found. From this fact it has been inferred that when the Zunis left New Mexico and Arizona they buried numerous springs, thus causing a fairly large supply of water to vanish without leaving a trace. Other ingenious hypotheses have been advanced, but the theory of changes of climate has in most cases been sedulously avoided, altho it fully explains all the facts and there seems to be nothing to oppose it.

The City of Mexico and Lake Tezcuco.—The City of Mexico lies 7,400 feet above the sea near the salt lake of Tezcuco, in a basin whose general physical features, apart from size, closely resemble those of the large basins of Lop and Seyistan. Historic records of the country extend back 600 years. During that time there appears to have been a slight, but appreciable change of climate in Asia, as has been shown in Part I, and the same seems to be true of Mexico. The evidence is somewhat masked by the fact that the natural course of events has been interrupted by various works of man, such as the dykes, canals, and tunnels, which have been built at various times since 1446 to regulate the waters of Tezcuco and its three tributary lakes. Nevertheless, there have been certain periods when nature has triumphed over human endeavor, and the waters have returned to the level which they would naturally occupy if man had never interfered. A comparison of the two chief epochs of this sort affords ground for the belief that the climate of North America has passed thru fluctuations like those which Asia has experienced.

The great authority on early Mexico is Humboldt, whose "Essai Politique sur la Royaume de la Nouvelle-Espagne" was published in 1811 as the third part of the "Voyage de Humboldt et Bonpland." Later and less authoritative writers such as Prescott[2] and Romero[3] follow him closely, adding little that is new. Humboldt specifically states his belief that the climate of Mexico in his day was more arid than it was at the time of the founding of the capital in 1325 A. D. He attributes the change in part to meteorological causes whereby evaporation has exceeded precipitation, and partly to the reckless destruction of forests by the Spaniards. He is sure that the level of Lake Tezcuco has fallen, thru natural causes as well as thru the works of man, and cites this fact as the chief evidence of a change of climate. In attributing the fall of the lake to the destruction of forests, he fails to consider that the removal of a protective covering of plants from the mountains might cause the summer rains to rush rapidly down the steep slopes which surround the basin, and thus decidedly raise the maximum level of high water, even tho the mean level might be lower than formerly.

The two periods at which it is possible to make a fair comparison of the earlier and later conditions of Lake Tezcuco are the interval from the foundation of the City of Mexico in 1325 to the Spanish conquest in 1520, and the interval from the great flood of 1629 to the middle of the next century, or 1755. The Aztec founders of Mexico, like most of the world's great races, came from the north. After a century or more of adventurous wanderings, enlivened by the vicissitudes of war, conquest, and slavery, they at length reached the shores of Tezcuco in 1325 A. D. Hoping for peace and safety, the Aztecs located themselves on some small islets several miles from the shore. There they laid the foundations of the present proud City of Mexico by sinking piles into the marshy shallows and erecting upon them light huts of reeds and rushes above the reach of the water. During the succeeding century, according to Humbold's lucid account, the city grew and prospered and its rule spread over the neighboring regions. It was still an island city with houses on piles, with canals instead of streets in many cases, and with canoes in place of beasts of burden. Sometimes it suffered when the lake rose more than usual; once, near the end of the fifteenth century, the water fell so

[1] E. Brückner: Klimaschwankungen seit 1700. Vienna. 1890.

[2] William H. Prescott: History of the Conquest of Mexico. Bk. I, III, IV.

[3] M. Romero: Geographical and Statistical Notes on Mexico. New York. 1908.

low that the city was in distress because canoes could not come to it with supplies of food from the country round about. In 1446 the first dyke was built to keep the water from the city in times of flood; but when Cortez came to Mexico in 1519 the capital was still a western Venice. He describes it as located on an island two leagues from the mainland. In order to besiege it effectively he was obliged to build brigantines, and in these he was able to sail completely around the city, except for a small distance on the southwest side toward Chapultepec, where the water was too shallow. The small boats engaged in ordinary traffic sailed everywhere, not only on Tezcuco, but on the other lakes and on the connecting rivers.

A century after the Spanish conquest the condition of the City of Mexico had changed. It had ceased to be an island, the canals had become dry; and wheeled vehicles had taken the place of canoes. This result was due in part to the construction of additional dykes, but nature apparently had been the main agent in the matter. Such seems to have been the opinion of Torquemada, a monk who lived in Mexico from the middle of the sixteenth century to the beginning of the seventeenth. He says, according to Prescott (page 33), that:

> As God permitted the waters which had once covered the whole earth to subside, after mankind had been nearly exterminated for their iniquities, so He allowed the waters of the Mexican lake to subside in token of good will and reconciliation after the idolatrous races of the land had been destroyed by the Spaniards.

About the time of Torquemada's death there occurred one of the periods of high water which, at that epoch, still periodically reduced the city to a partially inundated condition. To prevent such occurrence in the future a tunnel was built to carry off the surplus water of the Cuautitlan River. It might be supposed that after the construction of the tunnel the lake would never return to its natural condition. In 1629, however, during a season of uncommonly large floods the tunnel was stopped up completely. The City of Mexico was flooded for a time, but after a period of extraordinarily rainy years lasting till 1634, it became dry once more, altho neither the tunnel nor the old dykes were in a condition to prevent the rise of the water. Again, from 1675 to about 1755, the tunnel was closed completely, being filled with earth for an unknown distance. At the same time also the dykes were in poor repair, breaking whenever the water rose higher than usual. Nevertheless the city continued to stand on dry land. Sometimes, to be sure, a year of exceptional rains caused the water to rise sufficiently to flow into some of the streets, but not enough to do any serious damage. In other words, at the end of the seventeenth and the beginning of the eighteenth centuries the City of Mexico stood normally on dry land even without the aid of dykes or tunnels. Two or three hundred years earlier, on the contrary, the city was nominally a swamp island.

Further careful study is necessary before the cause of this change can be asserted positively. It is possible that the level of the ground in some parts of the city may have been artificially raised to an extent unknown by Humboldt. It is also possible that he, being prepossessed by an idea, may have given undue weight to phenomena which are undoubtedly much smaller and less significent than those in Asia. The level of Lake Tezcuco to-day depends entirely upon the works of man. However, human intervention does not seem to have been accountable for all of the fall in level between 1325, A. D., and the days of Humboldt. It is at least a fair working hypothesis that there has been a very slight permanent change of climate. Such an hypothesis seems to fit all the facts perfectly, but it can be proved or disproved only by further most painstaking investigation.

Evidence of change in South America.—Evidence as to the climate of the historic past is more abundant in South America and more conclusive than in North America. This is largely because the population of South America previous to the days of Columbus was more numerous and more civilized than that of North America, taken as a whole. Various authors have commented briefly upon this subject, and Bowman, in a paper read before the Association of American Geographers in December, 1907, has brought the subject into prominence by comparing the observations of Darwin and Moreno with his own important discoveries.[4]

The arid regions of South America consist of three chief parts. (1) In the first place a long narrow strip of desert extends along the western coast of the continent for about 30 degrees of latitude, from latitude 3° S., or a hundred miles south of Guayaquil to 32° S., or almost to Valparaiso, in Chile. Its dryness is due to the fact that it lies on the lee side of the lofty Andes in the zone of the southeast trade-winds, which lose their moisture on the east side of the mountains and become warm and very dry as they descend to the sea on the west. (2) The second extremely dry region lies east of the Andes and extends from about latitude 30° S. to nearly 50° S. Its aridity is due to the fact that it is located in the zone of prevailing strong westerly winds, which deposit their moisture in Chile, on the west side of the Andes, and accordingly are very dry when they pass over into Argentina and Patagonia. (3) The third region lies between the other two and extends roughly from latitue 15° S. to 30° S. It consists chiefly of a high plateau in Bolivia, within which lies Lake Titicaca and a great number of small salt lakes without outlets. Its aridity is due partly to its location in the subtropical zone of high pressure and descending, drying air and partly to the fact that it is entirely surrounded by lofty mountains which cut off much of the moisture which might otherwise be available. In all three of these dry regions of South America certain facts have been described which seem to indicate desiccation.

(1) *Jefferson's observations on the terraces of Peru.*—One of the first points on the west coast of South America at which the traveler arriving from the north finds himself face to face with the problem of desiccation is Lima, the capital of Peru, 12 degrees south of the equator. No one seems to have investigated the subject of desiccation critically in this region, altho numerous travelers comment upon the abundant and interesting evidences of more extensive cultivation in the past than in the present. The following statement, which has been kindly contributed by Prof. Mark Jefferson shows the nature of the phenomena and the importance which they may possess as indications of a most remarkable change in agricultural conditions either because of a change in climate or for some other reason, such as political upheavals, which, however, scarcely seem competent to produce all of the results described. Professor Jefferson's observations were made at a time when he was a keen-eyed young traveler rather than the careful scientist that he has now become; they deserve to be put on record, not only because of their intrinsic value, but also in order to stimulate further investigation. He writes as follows:

> The rainfall of Lima is very slight, amounting to only 46 millimeters (1.8 inches) as the average of six years' observations, according to Voss.[5]
>
> In estimating the significance of the phenomena here described it should be borne in mind that the terraces described below lie higher than Lima, and hence have a rainfall somewhat greater than the figure given above, altho still extremely meager.
>
> It is commonly said there, or was said at the time of my visit in 1886, that it rarely rains; and the wet sidewalks seen in the morning were ascribed to heavy dews. The triangle of cultivated land between Lima and Callao has its water from the river Rimac, and so do the fields on the valley floor that one follows, stream upwards, in making the railroad trip to Oroyo, up in the Andes. But the valley walls, which are all seamed with little terraces as the picture shows, are quite devoid of means of irrigation. The front of each terrace is a dry stone wall, and

[4] See the Geographical Journal. vol. 33, 1909. Man and Climatic Change in South America, by Isaiah Bowman.

[5] Die Niederschlagsverhältnisse von Südamerika. Ergänzungsheft 157 zu Petermanns Mitteilungen 1907.

the width is rarely so much as seven or eight feet. They were all dry, barren, and unused when I saw them in 1886. At the time when they were cultivated they must have depended upon rainfall, for there was no sign that irrigation brought water to them, nor could that have been done profitably with patches so small. In Lima, tho it rarely rains, the sky is often thick and hazy. An ascent of a few thousand feet up the mountain railway brings one into showers, there almost as incessant as the drought below. The present drought on the terraces seems to be due to a rising of the rain belt since Inca days.

(2) *Darwin's observations in Chili.*—Twelve hundred miles south of Lima, Darwin, the first of the authors referred to by Bowman in the article cited above, found phenomena which, like those of Lima, lie in the arid strip on the western flank of the Andes and suggest desiccation. He has described them in his classic volume, "The Voyage of the Beagle."

While traveling high among the Andes on their western side, about 30 degrees south of the equator, near the southern end of the sterile desert of northern Chile, Darwin came upon ruins in several places which are now uninhabitable. "Traces of Indian habitations have been discovered," he says (p. 409, edition of 1839), "in many parts of the Cordillera where the land is as utterly unfit for any kind of cultivation as it is near the Tambillos or Puente del Inca [two places where Darwin saw ruins]. * * * I have almost been inclined to speculate on the possibility of a small change of climate. In the Despoblado (uninhabited valley), near Copiapo, at a spot called Punta Gorda, I saw the remains of seven or eight square little rooms which were of a similar form with those at the Tambillos. They were situated in the most conspicuous and defenceless position, at the bottom of a flat, broad valley. There was no water nearer than 3 or 4 leagues, and that only in very small quantity, and bad; the soil was absolutely sterile; I looked in vain even for a lichen adhering to the rocks. At the present day, with the advantage of beasts of burden, a mine, unless it were very rich, could scarcely be worked there with profit. Yet the Indians formerly chose it as a place of residence! If at the present time two or three showers of rain were to fall annually, instead of one during as many years as is now the case, a small rill of water would in all probability be formed in this great valley, draining a mountainous country; and then by irrigation, the method which was formerly so well understood by the Indians, the soil might easily be rendered sufficiently productive to support a few families."

In explanation of the inferred change of climate, Darwin speculates on the possibility of its having been due to an uplift of the mountains, but is inclined to reject this hypothesis because of the length of time required for a movement of the land sufficient to produce the observed results. He dismisses the question with the suggestion that in some places the movements of the earth, which give rise to earthquakes, may have altered the courses of streams. He comes to no conclusion as to the cause, altho he seems to have little doubt as to the fact of change.

(3) *Moreno's observations in Argentina and Bolivia.*—Two or three hundred miles southeast of the district of which Darwin writes, and on the other side of the Andes in Argentina, Moreno, the second author cited by Bowman, describes other evidences of a change of climate, located in the second of the great dry regions of South America.[6]

In the gorges of the east side of the Andes between Valparaiso and Mendoza, there exist, he says—

extensive ruins where to-day life is extremely difficult or impossible during a great part of the year. * * * Extensive irrigation works are to be seen where to-day one could not possibly find a drop of water, showing that the climatic conditions of these regions have changed and that the waters must have diminished. It is known that a century ago the small lakes of Guanacache, between San Juan and Mendoza, were much more extensive, and that the Indians navigated them in the same manner as they navigate Lake Titicaca at the present time.

[6] F. P. Moreno: "Notes on the anthropogeography of Argentina." Geographical Journal, 1901, 18, p. 581 ff.

Moreno mentions other regions where similar phenomena are found. For instance, four or five hundred miles northeast of Mendoza, in latitude 27° S., the ruins of Pucara, in northwestern Argentina, lie on the southeastern slope of the plateau of Bolivia. Here—

the remains of walls and agricultural grounds show that the population numbered tens of thousands. To-day the waters of the valley are scanty and used only by a few descendants of the natives, possessing only a few goats and a little maize. In former times rains must have been frequent and water more abundant than it is to-day, as there are still visible small grounds in the rocky slopes which have been cultivated by natural supplies and not by irrigation, which would have been impossible.

This last statement, as Bowman points out, is particularly significant. The fact that certain areas which were once cultivated, are so located that irrigation would there be impossible even if there were a sufficient water supply shows that there must once have been rain enough to support crops. The fall of such rain must have been frequent enough to provide water not only for the unirrigated areas, but also for the large settlements whose ruins now remain.

In the region of Pucara and in the southern portion of the Bolivian plateau a little farther west, Moreno cites still further evidence of a similar nature to that given above. Near Pilchias and Constancias, two mining settlements, the miners discovered "old settlements and burial grounds in districts where now it is necessary to carry water for drinking purposes."

(4) *Bowman's observations on the old roads of Lake Huaco.*—The evidence of climatic change adduced by Bowman is of quite a different nature from that given by Darwin and Moreno. Seven hundred miles north of Darwin's region and still farther from the first of Moreno's sites, the basin of Huasco lies on the western edge of the Bolivian plateau in latitude 21° S. at an elevation of 13,000 feet above the sea. The basin is about 14 miles long from north to south, and 8 miles wide from east to west. Its floor is occupied by a shallow salt lake, which was formerly larger than it now is, as appears from the saline deposits which surround it, and from old beaches which lie at various levels above the salt plain. The lake has no outlet and changes in its level must be due to variations in the inflow or in the rate of evaporation. The surrounding country is uninhabited and there is not the slightest reason to believe that former tributaries of the lake have been diverted. Therefore changes in the water level must, it would seem, be ascribed to changes in precipitation or in evaporation, that is to changes in climate.

The west side of the Huasco basin is bounded by a steep scarp at the foot of which several springs of water flow forth. Near the springs stand a number of corrals used by travelers along the various llama trails which radiate from this point. One of the trails runs south and east around the southern side of the lake to the southeast corner of the basin. It follows the shortest possible line from spring to spring, a line which has the further advantage of lying as close to the lake as possible, in the narrow strip where alone grass is found. A mile or so to the south of the modern road the faint marks of an older trail may be seen. The old trail follows closely the line of an elevated strand 150 feet above the present level of the lake. Beside it lie piles and lines of stones, such as are built beside all roads in this part of the lofty plateau of Bolivia. Several stone corrals are located at the roadside in highly exposed situations close to little valleys which are always dry, except during the few days when snow is melting or when a rare thunder-storm occurs. There is no grass anywhere along the road, nothing but bare gravel. There seems to be absolutely no reason for the location of a road along this line unless the climate of the past was such that the lake rose toward the level of the old strand, and that the now dry valleys contained running water which would give cause for the location of corrals beside them. If this were the case the position of the trail is highly sensible. It follows the shortest line

which was then possible; and the corrals are located at exactly the places where water would naturally be found, and in the only place where grass would be abundant, namely, in the strip close to the lake. Unless the climate of the past were different from that of the present, the location of the road, as Bowman says, is absurd.

The change from the old trail to the existing routes does not seem to have been immediate. On the contrary there must have been an intervening period when a road existed along an elevated strand of the lake which lies 50 feet above the modern level and 100 feet below the main old road. The top of the 50-foot beach, as Bowman puts it—

> Is criss-crossed by old and now somewhat faint llama trails. These have a peculiar braided pattern everywhere, an unmistakable design caused by the irregular march of this erratic beast as it wanders this way and that from the general route. Not even a vagrant llama would follow the route to-day because of the absence of food as contrasted with its presence on the alluvial slope and basin floor just below. Much less would such a course be followed by a caravan. The consideration of changing lake level having temporarily forced the road to this higher level in response to cyclic climatic changes of short duration, is excluded because these fluctuations are but a few feet in value at the most, as marked by the saline deposit that the waters form and is indicated by the fact that the corrals, huts, and trails now in use are at various intermediate levels between the 50-foot beach and the basin floor. While one must admit less certainty in this case than in the other, it is again a much more reasonable view that the trails were made at a time when the lake waters stood near the level of the old beach and no better course could be found by the traveler than the relatively flat-topped beach, rough and stony as it is.

Similarity of phenomena of desiccation in the Old World and the New World.

The American phenomena described in the preceding pages are closely similar to phenomena of the same nature in Asia. For instance, the ancient strands of Great Salt Lake are of the same sort as those of the Caspian Sea, Lop Nor, and the lake of Seyistan. The Zuni ruins of New Mexico are closely comparable with scores of waterless ruins in Persia, Transcaspia, and Chinese Turkestan. The apparent decrease in the size of Lake Tezcuco during the last five centuries appears to have taken place synchronously with a similar decrease in the size of Lop Nor, the lake of Seyistan, and other Asiatic lakes. The terraces of Lima and the unwatered fields in Argentina and Bolivia, described by Moreno, present the same characteristics as the so-called Ghorband, or abandoned, unirrigated terraces and fields in the driest parts of Baluchistan. Darwin's huts and small village sites are almost identical in nature with old shepherds' huts and little agricultural villages whose ruins are now found in the Kuruk Tagh, or Dry Mountain region of far western China. (See fig. 3.)

In the case of the old roads and strands of Lake Huasco in Bolivia and Lop Nor in Chinese Turkestan, the similarity is almost startling. In both cases the modern road follows a direct route thru what was once a part of the bed of the lake. Above each modern road lie two ancient roads. One runs along a fairly well-marked strand indicating a relatively slight change in the dimensions of the lake. The other, a much more important road, lies along a strand which is located higher than the preceding and which indicates a much greater expansion of the water. The upper road in both cases is plainly marked by the customary piles of stones. All four roads, two in the middle of South America and two in the heart of Asia, are utterly inexplicable and are absurdly located, unless it be supposed that the climate of both continents has been subject to cyclic changes of considerable magnitude. (See figs. 1 and 2.)

A careful review of the phenomena described in the preceding pages and of other facts not here set forth, makes it hard to avoid the conclusion that the climatic histories of the continental regions of the Old World and the New World have been essentially the same. Cyclic changes appear to have been the rule; but the cycles have been of varying lengths, and have given rise to varying degrees of aridity, warmth, and the other elements which together constitute climate. On the whole, there seems to have been an increasing degree of warmth and aridity.

III. GENERAL CONCLUSIONS.

The cause of climatic changes.—It is beyond the province of this article to discuss at any length the problem of the cause of changes of climate. Nevertheless there are two points which spring naturally from the preceding discussion. In the first place, if the conclusions of this article are valid, there is no gap between the great climatic cycles of the glacial period on the one hand, and the small 11-year or 36-year cycles of the present day on the other hand. Between the two there are other cycles, the so-called "stages" which are known to have characterized the final phases of the glacial period and the briefer, but from the human standpoint more important, cycles of the historic period, the whole forming one great series. The small cycles of 11 or 36 years appear to be of the same nature as the large cycles, historic or glacial, so far as can be judged from their effects. The only difference appears to be in magnitude. This suggests that the cycles of all kinds may be due to a common cause. In the second place the change in temperature which students of the glacial period consider necessary in order to induce glaciation, is slight. Changes of a few tenths of a degree in a century appear at first thought to be of little importance, but geologists and students of the physics of the earth hold that such changes are capable of producing momentous results.

Various investigators, among whom Brückner,[7] Bigelow,[8] and the Lockers[9] hold a foremost place, believe not only that small climatic cycles exist with periods of from 3 to 36 years, but also that the cycles have a definite relation to variations in the activity of the sun. The solar variations are indicated by changes in the number and size of sun-spots or in the rapidity with which one sun-spot maximum succeeds another. Another set of investigators, among whom the most noteworthy are Langley and Abbott,[10] Köppen,[11] and Newcomb,[12] have studied the temperature of the earth's atmosphere in relation to changes in the sun. They have all concluded that the mean temperature of the earth varies in response to variations in the amount of heat received from the sun. Their figures differ markedly, but all agree that the amount of radiation from the sun actually varies.

Newcomb's study of the relation of the temperature of the sun to that of the earth is the most recent, comprehensive, and accurate that has ever been made. His conclusions are so careful and conservative that they can scarcely be doubted so far as they are based directly upon statistics. He expresses himself thus (p. 379): "A study of the annual departures [from mean temperature] over many regions of the globe in equatorial and middle latitudes, shows consistently a fluctuation corresponding with that of the solar spots. The maximum fluctuation in the general average is 0.13° C. on each side of the mean for the tropical regions. [The maximum temperature coming at times of minimum sun-spots]. The entire amplitude of the change is therefore 0.26° C. [0.47° F.], or somewhat less than half a degree of the Fahrenheit scale." On an earlier page (341) he says: "Altho the reality of this 11-year fluctuation [both solar and terrestrial] seems to be placed

[7] E. Brückner: Klimaschwankungen seit 1700.

[8] F. H. Bigelow: The relations between the meteorological elements of the United States and the solar radiation. Am. Jour. Sci., 1908, **25**: 413–430. Also Monthly Weather Review, various articles, 1902–1905.

[9] N. and W. J. S. Lockyer: Nature, 1901, **64**: 196–197. Proc. Roy. Soc., 1901, **69**: 285–300; and 1902, **70**: 500–504.

[10] S. P. Langley: On a possible variation of the solar radiation and its probable effect on terrestrial temperatures. Astrophysical Journal, 1904, **19**: 305–321.

[11] Köppen: Zeitschrift der Oesterreichischen Gesellschaft für Meteorologie. VIII Band. 1873.

[12] Simon Newcomb: A search for fluctuations in the sun's thermal radiation thru their influence on terrestrial temperature. Trans. Am. Philos. Soc., Philadelphia, 1908, **21** (n. s.): 309–387.

beyond serious doubt, the amplitude being several times its probable error, its amount is too small to produce any important direct effect upon meteorological phenomena." Again, on page 384 he puts in italics the last part of the following quotation: "It follows as the final result of the present investigation that *all the ordinary phenomena of temperature, rainfall, and winds are due to purely terrestrial causes, and that no changes occur in the sun's radiation which have any influence upon them.*"

While Newcomb's conclusion as to the change of temperature between the times of maximum and minimum sun-spots rests upon unassailable evidence, his last conclusion as to the relation of the changes to meteorological phenomena is based purely on inference and is open to question. He has failed to consider the effect which a slight change of temperature may have upon meteorological conditions provided it be permanent. In his 11-year cycle the range of temperature is 0.26° C. In order to estimate the true importance of such a variation, it is necessary to consider what would be the result if the temperature no longer fluctuated back and forth between the two extremes every eleven years, but remained constant at one extreme for a few centuries and then at the other for a corresponding length of time.

In order to explain the glacial period, geologists and students of "paleo-meteorology" postulate a change of the mean temperature of the earth's atmosphere many times larger than Newcomb's change in the 11-year cycle, but not of a different order of magnitude. Penck, the leading German student of glaciation, believes that a permanent change of 5° C. in temperature is sufficient to account for the difference between the conditions of the glacial period and those of to-day.

According to Ekholm,[13] a lowering of the mean annual temperature to the extent of from 7° to 9° C. would cause the snow-line of the earth as a whole to descend 3,300 feet, and would lead to a revival of the glacial period. Bonney[14] says that during the glacial period the temperature of England was about 20° F. lower than it now is, and the mean temperature of the earth's atmosphere as a whole was from 15° to 20° F. lower than at present. Brückner states that a lowering of the earth's temperature to the extent of 3° or 4° C. would suffice to account for the phenomena of the glacial period. He considers that the change in temperature would be relatively slight in equatorial regions and great in polar regions. Finally David,[15] from a study of glaciation in Australia and other less familiar parts of the world, arrives at the conclusion that in order to explain the phenomena of the last great advance of the ice it must be assumed that the temperature of that time was lower than that of the present by "probably not less than 5° C."

The mean value of the decrease in temperature necessary to produce a glacial period, according to the statements of the five authorities cited above, amounts to from 5° to 6° C. That is, if the mean temperature of the earth were to fall 5° or 6° C., and were to remain thus low for a sufficient length of time, meteorological conditions would be so altered that most of North America would be shrouded with ice down to about the fortieth degree of latitude, and Europe would suffer a corresponding glaciation. If a change of from 5° to 6° C. would produce such a result, it seems reasonable to suppose that the change of 0.26° C. which Newcomb has determined in the 11-year sun-spot cycle would produce a corresponding result on a smaller scale, provided the duration of the period of low temperature were long enough. To take a specific case for illustration, the Rhone glacier[16] is now barely 6 miles long; the foot of the ice stands at a height of 5,780 feet above sea-level, and the surface of the ice at its origin is 10,200 feet above the sea. During the period of maximum glaciation the glacier was 240 miles longer than it now is; its foot stood about 4,700 feet lower than is now the case, and its surface near the origin was 1,400 feet above the present surface. For the sake of conservatism, let it be assumed that the change of temperature necessary to cause the Rhone glacier to assume its former great dimensions was 13° C., which is greater than the maximum figure given above (Bonney's, 20° F., or 11.1° C.), and more than twice the mean of the five authorities cited. Then a change of 0.26° C. would be one-fiftieth of the change necessary to cause the Rhone glacier to assume the dimensions which it had during the glacial period. It seems fair to assume that the results of a small change of temperature would be approximately proportional to those of a larger change. If this is so, the difference of 0.26° C., which Newcomb finds between the mean temperature of periods of minimum sunspots and those of maximum sunspots would cause pronounced changes in the Rhone glacier, provided the low temperature lasted long enough to allow of the abundant accumulation of snow. In that case, if the form of its valley were favorable, the Rhone glacier might become 5 miles longer than it now is; or, if the gradient of the valley bottom be assumed as uniform, the ice might descend 90 feet below its present level; or the glacier might increase 28 feet in thickness. The exact nature of the change in the glacier, and its exact dimensions would depend upon the topography of the Rhone Valley and upon the relation of precipitation to temperature, but the figures which have just been given show the order of magnitude of the results which would be effected by a permanent lowering of the mean annual temperature of the earth to the extent of 0.26° C. A change of temperature capable of producing such results or even results one-half as great can scarcely be said to be too small to produce "any important effect upon meteorological phenomena."

In conclusion it seems reasonable not only to conclude with the astronomers that at the present time the sun is subject to cyclic variations having a period of eleven years, but also that the variation in an average cycle is sufficient to cause changes in meteorological phenomena so important that if given time they would produce marked results. The effects of small cycles apparently differ only in magnitude from those of the historic cycles whose existence is indicated by abundant evidence both in Eurasia and in America; and these in turn are of essentially the same nature as the cycles of the glacial period. If the small changes of the 11-year cycles are due to variations in the intensity of the sun's radiation, there seems to be no reason why the large changes of past times may not be due to the same cause. As yet there is no evidence whatever to prove that the intensity of solar radiation does or does not fluctuate in periods of long duration. The radiation of other stars, however, is known thus to fluctuate. It is a fair working hypothesis that the sun is a variable star which in the course of great geological ages has past thru changes of every degree, and that even now the climate of the earth still varies in harmony with the globe upon whose rays all movement and life depends.

[13] Quart. Journ. Geol. Soc. of London, 1902, **58**:39.
[14] Nature, 1903, **67**:150.
[15] Congrès Geologique International. Compte Rendu de la X^me^ Session. 1906. p. 468.
[16] Jas. Geikie: The Great Ice Age. 3d edition. 1894. p. 543 ff.

WEATHER BUREAU MEN AS EDUCATORS.

The following text summarizes the educational work done by local Weather Bureau men during the year 1908, so far as it has come to the notice of the Editor:

Prof. A. G. McAdie reports an introductory lecture on January 16, by himself, and a four months' course of two lectures weekly as an elective in the State School of Agriculture, and an obligatory course for candidates for the Teacher's Certificate in Physical Geography, at the University of California, Berkley, Cal., by Dr. C. Abbe, jr., Observer.

D. Cuthbertson, Local Forecaster, Buffalo, N. Y., reports visits by classes from local schools on February 1; March 9, 10, and 11; April 8, 9, and 25. On February 13, he gave an extended talk on "The value of the Weather Bureau to navigation" in the club rooms of the Shipmasters' Association of the Great Lakes. His first lecture before this association was given in 1892.

J. R. Weeks, Local Forecaster, Binghamton, N. Y., reports that the popular lecture with lantern slides, prepared by him in 1907, has been used for one or two weeks each at twenty-four places in New York and one each in Nebraska and Indiana. The lantern slides were also used by W. M. Wilson, Section Director, for short talks at the State Fair, at Syracuse, in connection with the exhibit of the New York State College of Agriculture.

E. L. Wells, Section Director, Boise, Idaho, reports visits by classes from local schools on August 4, October 16, and November 25. He also gave lectures illustrated by lantern slides loaned from the Central Office, on January 3, 20, and 23, November 25, December 7, 16, and 22.

M. L. Fuller, Observer, and Professor of Meteorology in the St. Lawrence University, delivered lectures before the Clarkson School of Technology at Potsdam, N. Y., during March, April, and May, in continuation of a similar series the previous year. Both these and his regular lectures at Canton, N. Y., with the accompanying examinations, count toward the Baccalaureate degrees of the University of the State of New York, whose central office is at Albany. An approximate record of his work for the year is as follows: During the first half year in the College of Letters and Science, three hours weekly in "Elementary Meteorology" to 11 students. During the second half year three hours weekly on "General Climatology" to 19 students; three hours weekly on "Advanced Meteorology" to 11 students. In the School of Agriculture, ten hours on the general work of the Weather Bureau and on "Climatology;" at the Clarkson School six lectures on "Economic Hydrology;" before agricultural societies, 3 lectures. Similar work was done during the autumn of 1908. An address was given December 30, 1908, before the South Bristol Farmers' Club at New Bedford, Mass.

E. W. McGann, Assistant Observer, Charles City, Iowa, reports visit by classes from the local high school on January 17.

Prof. H. J. Cox, Chicago, Ill., reports visits from classes and students in the local schools on March 4, 5, 10, 11, 12, 26, 27, and 30; April 1, 3, 6, 7, 8, 9, 10, 11, 13, 20, 21, and 24; May 5, 6, 7, and 22; June 1, 2, 3, 4, 5, and 18; in all, since September 1907, 40 classes averaging 25 students each. There is scarcely a week day at this station on which visitors do not ask to be shown thru the office and the time given to this work is very considerable. On March 11, Professor Cox gave an address before the teachers of physiography and astronomy in the Chicago high schools, on "The frost and temperature conditions in the cranberry marshes of Wisconsin."

S. S. Bassler, Local Forecaster, Cincinnati, Ohio, reports giving an address on the Weather Bureau May 11, 1908, at the twelfth annual banquet of the Manufacturers' Club of Cincinnati.

J. W. Bauer, Section Director, Columbia, S. C., reports giving three class-room lectures on meteorology, weather forecasting, and climatology, respectively, on January 20, 22, and 24, to the class in physiography at the University of South Carolina.

J. Warren Smith, Section Director, Columbus, Ohio, reports giving a lecture on January 23, on "The protection of crops from frost;" and again, January 24, on "Protection from lightning," before the students in the Short Course on Agriculture at the Ohio State University. Copies of these lectures have been published and widely circulated by the Associated Farm Press of Chicago and New York. Mr. Smith's regular course in meteorology consists of lectures twice a week during twelve weeks, optional in the College of Arts, but obligatory for juniors in the College of Agriculture, Ohio State University. Classes from local schools visited the office on January 14 and 16. On November 27 Mr. Smith read two papers, "Evaporation" and "Rainfall and crops," before the Ohio Academy of Sciences at Granville.

J. W. Byrom, Observer, Concordia, Kans., reports that classes from local schools visited the office on March 30, April 7, and October 20.

Joseph L. Cline, Observer, Corpus Christi, Tex., reports that during the academic year ending May 28, 1908, he delivered a series of 38 lectures on meteorological and climatological subjects to the senior class of the Corpus Christi High School. Also one lecture, June 17, to the students of the Corpus Christi Summer School. The series of lectures before the high school was resumed in October, 1908, having already been delivered for three consecutive years. This school affiliates with the State University at Austin, Tex.

J. M. Sherrier, Local Forecaster, Davenport, Iowa, reports that he delivered an address on February 26 before the Davenport Academy of Sciences on "Winter storms and cold waves." On January 17 he gave a lecture before the Men's Club, Rock Island, Ill., on "The practical work of the Weather Bureau."

W. U. Simmons, Assistant Observer, Del Rio, Tex., reports he delivered a lecture, February 21, before the Southwest Texas Sheep and Goat Growers' Association on "The distribution of Weather Bureau forecasts." The immediate result of this lecture was an extensive increase in the establishment of telephones within 100 miles of the station.

F. H. Brandenburg, District Forecaster, Denver, Colo., reports a lecture, illustrated by lantern slides loaned by Colorado College, on "Weather forecasting," on February 29, before the Colorado Polytechnic Society of Colorado Springs, assembled at Gleneyrie, the home of Gen. W. J. Palmer.

Norman B. Conger, Inspector, Detroit, Mich., reports that classes from the local schools visited the office, December 4 and 11; and that he gave an informal talk on November 24, before the Credit Men's Association.

James H. Spencer, Local Forecaster, Dubuque, Iowa, reports that on January 23, he delivered an address on "Weather signs and sayings" before the members of St. Luke's Fraternity. On May 16, an address before the Dubuque Teachers' Association. On May 22, a lecture on "Storms" before the alumni and teachers of St. Joseph's Academy. On April 23 the Dubuque Boys' Club visited the local office.

H. W. Richardson, Local Forecaster, Duluth, Minn., reports that on January 31 he delivered an address at the Lester Park Methodist church; also on December 8 on the Weather Bureau before the Duluth-Superior branch of the National Association of the Jobbers' Credit Men. He also reports visits from local schools, usually followed by an address of an hour's length, on May 22, October 13, October 22, and December 4.

A. L. Brand, Local Forecaster, Evansville, Ind., reports that on January 14 he delivered a lecture on the Weather Bureau before the Men's Club; also on November 13 a lecture before the Evansville Business Association.

C. F. von Herrmann, Section Director, Erie, Pa., reports that on March 15 a class from Harbor Creek High School visited the office.

W. W. Neifert, Local Forecaster, Hartford, Conn., reports that on January 22 he gave an address at the Walnut Lodge Hospital; on February 28, an informal talk at St. John's Episcopal church; on April 28, an address before the Weathersfield Grange; May 25, an address before the Men's Club. On February 4 and 5 the office was visited by local classes; on May 9 by members of the local teachers' convention.

W. B. Stockman, Section Director, Honolulu, H. I., reports visits from classes of Oahu College on May 20 and 28.

Dr. W. M. Wilson, Section Director, Ithaca, N. Y., reports that a series of lectures, laboratory exercises, and field observations designed to meet the needs of teachers of physical geography, amounting to four hours weekly, were given by him during tbe session of the Cornell Summer School, Ithaca, N. Y.

W. J. A. Schoppe, Assistant Observer, Iola, Kans., reports visits from classes of local schools on March 30 and 31, April 24, and May 18.

P. Connor, Local Forecaster, Kansas City, Mo., reports a lecture on "Weather and Advertising" before the Men's Club on January 28; also a lecture on February 9 on "Sixteen months of life on the islands off the coast of Washington and the work of the Weather Bureau."

F. E. Hartwell, Assistant Observer, Key West, Fla., reports a series of short talks before the public schools every Friday, beginning February 21, concerning the atmosphere, storms, weather bulletins, etc.

J. F. Voorhees, Observer, Knoxville, Tenn., reports seven lectures on elementary meteorology, instruments, and forecasting before 65 students in the tenth grade of the Knoxville High School October 3, 4, 7, 8, 9, 10, and 11, 1907; on October 10, 1907, a talk before the Farragut School, Concord, Tenn.; on November 5 and 12, 1907, the first two lectures of a series at the Knox County Central High School, Fountain City, Tenn. Lectures to students of the University of Tennessee January 10, 15, and 17, 1908; a lecture at Lincoln Memorial University, Cumberland Gap, on February 25; before the Knox County Truck Growers' Association, March 7; two half-hour talks before the night school for working men; two half-hour talks before the Hampton-Sidney School; three one-hour talks before the Park City High School. Forty copies of "Notes on Frost" were distributed and many fruit and truck growers persuaded to make preparation for protecting their crops from frost; all who tried the experiment were pleased with the results. "My observations this spring in orchards of apple, peach, plum, and cherry trees seem to indicate that the ability of a tree to resist frost varies greatly with its stage of development, and that varieties that at a certain stage would be injured will at a later stage stand a much lower temperature without injury. The subject is worthy of investigation, as definite knowledge along this line would be very valuable."

G. Harold Noyes, Local Forecaster, Lexington, Ky., reports that during May and November, 1907, and January, 1908, short series of talks were given to students in the agricultural department of the Kentucky State University.

H. F. Alciatore, Section Director, Little Rock, Ark., reports illustrated lectures on the work of the Weather Bureau January 7 and 8 before the University of Arkansas at Fayetteville and before the high school at Fort Smith; a lecture on "Synoptic Forecasting" on March 20, before the Arkansas Polytechnic Society; on March 26, a lecture before the Women's Cooperative Association; March 27, a lecture before the Central Young Men's Christian Association; December 5, an address before the Arkansas River Convention on "The regimen of the Arkansas River." Classes and teachers from local schools visited the office on December 29 and 30.

A. B. Wollaber, Local Forecaster, Los Angeles, Cal., reports visits by classes of local schools during March, May 12 and 16, and October 21.

H. R. Patrick, Observer, Marquette, Mich., reports that he delivered an address on March 10 before the Northern State Normal School, and that on March 26 the same class visited the local office.

Albert Ashenberger, Local Forecaster, Mobile, Ala., reports that the class in physical geography of Barton Academy visited the office on January 14, November 19, and December 9.

F. P. Chaffee, Section Director, Montgomery, Ala., reports that classes from local schools visited the office March 27 and April 3. He delivered a lecture before the Alabama Polytechnic Institute, Auburn, Ala., on March 30.

H. W. Grasse, Observer, Moorhead, Minn., reports that a class from Fargo College, Fargo, N. Dak., visited the office May 1.

Charles A. Hyle, Observer, Minneapolis, Minn., reported an address on October 14, 1907, before the Medical Department of Hamline University; repeated and extended, by request, on October 21.

William A. Shaw, Local Forecaster, Northfield, Vt., reports a series of 24 lectures before the senior class of Norwich University completed May 13, 1908. This course is two hours weekly during the winter term, and is obligatory for graduation. Mr. Shaw has given this course for the past twelve years without compensation, and ranks as a member of the faculty with the title of professor of meteorology.

Dewey A. Seeley, Observer, Peoria, Ill., reports that during the college year closing June 13 he gave lectures before the classes of the Bradley Polytechnic Institute on November 15, 1907, and June 9, 10, and 11, 1908. Classes visited the local office on April 15 and June 12.

T. F. Townsend, Section Director, Philadelphia, Pa., reports that G. S. Bliss, Observer, addrest classes of the Northeast Manual Training School on January 20 and 30; also the Science Club at George School on February 17.

E. A. Beals, District Forecaster, Portland, Oreg., reports that classes from local schools visited the office on March 12 and 25 when the work of the Bureau was explained by E. B. Gittings, jr.

M. E. Blystone, Local Forecaster, Providence, R. I., reports lectures before the local Men's Club on October 15 and 19.

L. H. Daingerfield, Local Forecaster, Pueblo, Colo., reports that classes from local schools visited the office on January 14 and 17, March 6, and April 15. An illustrated lecture was delivered before the Sociological Department of the Colorado Fuel and Iron Company on April 21; another lecture was given April 30 before the Crews-Beggs Commercial Club; and on May 8 before the Columbian School.

A. H. Thiessen, Section Director, Raleigh, N. C., reports that on May 8 he completed the usual course in meteorology and climatology given to the senior class of the State College of Agriculture and Mechanics, one hour weekly for three months.

R. J. Hyatt, Section Director, Salt Lake City, Utah, reports visits from local schools January 25, 26, and April 7.

Maurice Connel, Observer, San José, Cal., reports two lectures before the Chatauqua Assembly July 17 and 18, and a lecture before the San José Normal School March 23.

Wm. M. Dudley, Local Forecaster, Scranton, Pa., reports a visit from a local school January 15; an address January 28 during the "noon hour" to the employees of the Delaware, Lackawana, and Western Railroad under the auspices of the local branch of the Railroad Young Men's Christian Association. "At the request of the foreman I had a frame and daily weather map sent to the shop, but a few days later he wrote me as follows: 'I have posted the weather maps sent me from your office, and find that it takes too much of the men's time

to study them during working hours, so I herewith return to your office by messenger the frame you so kindly sent me and hope you will discontinue sending the maps.'"

G. N. Salisbury, Section Director, Seattle, Wash., reports he completed the course of fourteen lectures before the State University Summer School on August 2; conducted a class in practical meteorology at the State University, giving twenty lessons, lectures, quiz, and laboratory work between October 9, 1907, and January 24, 1908; a lecture before the Young People's Science Meeting February 6, 1908; visits from local classes February 8, 1908.

Charles Stewart, Local Forecaster, Spokane, Wash., reports a visit from local classes May 13.

Wm. G. Burns, Section Director, Springfield, Ill., reports an address at Whitehall, Ill., before the Teachers' Institute, July 26, 1907; at Lincoln, Ill., February 27, 1908, and Springfield, Ill., March 3, 1908.

N. R. Taylor, Local Forecaster, Springfield, Mo., reports visits from local classes January 28 and 29; February 20, 21, and 22.

R. H. Sullivan, Local Forecaster, Wichita, Kans., reports an address before the Sedgwick County Horticultural Society March 5, and before the Plymouth Brotherhood on May 11, which was repeated May 20.

Charles A. Hyle, Observer, Yellowstone Park, Wyo., reports a visit on August 15 by the summer class of the Montana School of Mines, Butte, Mont.

THE DIURNAL VARIATION OF THE RAINFALL AT KINGSTON, JAMAICA.

By MAXWELL HALL, Government Meteorologist, Chapelton, Jamaica.

[Reprinted from Jamaica Weather Report, October, 1908.]

The United States meteorological station in Kingston is provided with a self-registering rain-gage which measures the amount of rain fallen at intervals of time, so that the diurnal variation will be very accurately known in the course of a few years.

But the diurnal variation is now required for certain physical problems, it occurred to me that by reducing the notes made by Mr. Robert Johnston, in the large Kingston registers between 1881 and 1896, inclusive, a close approximation would be obtained.

The registers give the amount of rain fallen during any day, and the notes give the time at which the rain fell, or its duration if prolonged; and their reduction was made under my supervision by Mr. L. Maxwell Hall.

The mode of reduction was to ascertain the total amount of rain recorded for each hour for each month; and then various groups were formed to show that the characteristics were consistent thruout the whole series, and not dependent on seasons, or any particular year or years.

The following table gives the amount of rainfall for the sixteen years for each hour for spring and summer, or from March to August, inclusive; for autumn and winter, or from September to February, inclusive; and for the whole year. The last column gives the percentage for each hour for the whole series.

From this table we see that the rainfall is least at midnight, that it increases more or less regularly to 3 and 4 p. m., that there is a very small maximum at 2 and 3 a. m.; another small maximum at 7 and 8 a. m. and then the large maximum at 3 and 4 p. m.; after which it decreases more or less regularly to the minimum at midnight.

Table showing the diurnal variation of the rainfall at Kingston, Jamaica.

Hour.	Spring and summer.	Autumn and winter.	Whole year.	
	Inches.	*Inches.*	*Inches.*	%
1 a. m.	6.85	4.85	11.70	2.3
2 a. m.	10.63	8.05	18.68	3.6
3 a. m.	9.32	8.62	17.94	3.5
4 a. m.	8.74	8.22	16.96	3.3
5 a. m.	8.94	7.65	16.59	3.3
6 a. m.	10.53	8.00	18.53	3.6
7 a. m.	12.83	11.27	23.80	4.7
8 a. m.	12.92	11.03	23.95	4.7
9 a. m.	10.89	10.54	21.43	4.2
10 a. m.	10.09	8.63	18.72	3.6
11 a. m.	9.95	7.31	17.26	3.2
Noon.	11.61	11.30	22.91	4.5
1 p. m.	16.09	13.68	29.77	5.8
2 p. m.	18.55	16.52	35.07	6.8
3 p. m.	24.57	18.63	43.20	8.5
4 p. m.	26.60	17.20	43.80	8.6
5 p. m.	18.83	12.50	31.33	6.1
6 p. m.	13.12	10.49	23.61	4.6
7 p. m.	11.05	7.95	19.00	3.7
8 p. m.	8.28	6.33	14.61	2.8
9 p. m.	6.41	5.38	11.79	2.3
10 p. m.	6.04	4.42	10.46	2.1
11 p. m.	5.55	6.19	11.74	2.3
Midnight	5.64	3.82	9.46	1.9
Sums	283.73	228.58	512.31	100.0

These characteristics permeate the whole series; month after month, year after year, the same features are more or less strongly marked; and they are also reproduced by the self-registering rain-gage for the spring and summer of the present year (1908).

It is therefore quite clear that we are dealing with important physical phenomena, tho their explanation may be hard to find.

THE TEACHER AND THE STUDENT.

The good work that is done in meteorology is often accomplished by young students working under the experienced guidance of some university professor. The theses submitted by students for the attainment of the higher collegiate degrees are very apt to give summaries of our present knowledge from some new points of view and to suggest or even demonstrate some advance in knowledge.

It is thru his scholars, by giving them his best ideas and guiding them as they work, that a teacher may hope to accomplish for his special branch of science far more than he could do single-handed. The best teachers hold the future of science in their hands. Their own broad views and high aspirations must be imprest upon all with whom they come in contact, and especially must young students be inspired to enthusiasm and devotion. The teacher is not to dwell too deeply on his own trials, to lose patience, or to be discouraged by overwork, poor laboratories, meager libraries, and want of sympathy; he must overcome these by his own force of character. He is expected to be optimistic in the midst of discouragements. There are always obstacles in the way of success, he who yields and settles down to merely getting a living out of his professorship, represents the lowest grade of the university professor. He who lets every one know his higher aims and hopes, and keeps his students working up toward the researches that he would himself carry out if possible, will surely find enthusiastic helpers. The men who put their science first and their troubles and difficulties last, are those whom the world admires and loves to copy, and who inspire the world.—*C. A.*

ANNUAL REPORT BY WILLIS L. MOORE, CHIEF OF THE WEATHER BUREAU, FOR THE FISCAL YEAR ENDING JUNE 30, 1908.

[Dated September 28. Extract from the report of the Secretary of Agriculture for 1908.]

I have the honor to submit a report of the operations of the Weather Bureau during the fiscal year that ended June 30, 1908.

RESEARCH AT MOUNT WEATHER.

As stated in my last report, the administration building was totally destroyed by fire October 23, 1907. The destruction of the living quarters made it imperative to shelter the employees in such places as could be temporarily adapted to living purposes. Accordingly, portions of the farm cottage, hitherto occupied by the laborers, and of the power house, the barn, and the stable were utilized for sleeping, eating, and cooking purposes. With one exception, these buildings were not suitable for living quarters, especially during the inclement weather that prevails at Mount Weather in the winter season. Notwithstanding this fact, the work of the observatory was carried on without complaint and with no material curtailment. Under the circumstances, however, it was impossible to enlarge the scope of the work.

The activities of the year may be classified under the following heads:

DAILY METEOROLOGICAL OBSERVATIONS.

Regular twice-daily observations of pressure, temperature, humidity, wind, and weather were made. These observations were telegraphed to the Central Office in Washington for the use of the Forecast Division.

UPPER-AIR RESEARCH.

During the year that ended June 30, 1908, records of pressure and temperature were obtained daily, except Sunday, by means of kites and captive balloons. These records were computed for each day so as to show all peculiarities or changes in the temperature gradient or air currents, altitudes of clouds, depths of cloud and fog layers, and the highest points reached. The tabulated results, together with observations and conclusions deduced from them, have been published in the Bulletin of the Mount Weather Observatory. Two numbers of this publication have already appeared, the third is nearly thru the press, and the manuscript of the fourth is about ready for the printer. Daily upper-air data are also telegraphed to Washington for the Forecast Division.

The records are for the most part obtained by means of kites. On occasional days, when the wind is insufficient for kite flying, captive balloons are used. The mean altitude obtained during the year with captive balloons was 2,357 meters (7,732 feet). With the installation of the new kite reel, designed to carry 15,240 meters (50,000 feet) of wire and to run at rates of speed varying from 0.45 meter to 4 meters per second (1 to 9 miles per hour), the observatory will be well equipped for kite flying. The balloon ascensions during periods of very light winds are of great importance, in that they make the upper air records continuous. Their need will justify the equipment of the observatory with the means of making and repairing its own balloons, and with a gasometer suitable for storing the gas that has been used in an ascension. At present this gas is wasted, and the capacity of the gas plant is insufficient to permit the use of more than one balloon in an ascension, while two could often be used to great advantage.

The only records now obtained are those of temperature, pressure, and wind direction. Instruments have been ordered, however, which will record the relative humidity also, and plans are being made to secure a record of the wind velocities in the upper atmosphere and to make the kites and balloons a means of studying the electrical conditions obtaining at similar heights.

The observatory also cooperates with the International Commission of Aeronautics in its endeavor to secure on fixt days upper-air data for a number of stations in the Northern Hemisphere.

WORK OF MAGNETIC OBSERVATORY.

The work in terrestrial magnetism was interrupted and seriously set back by the burning of all its records in the fire that destroyed the main building. In beginning anew, advantage was taken of the opportunity to rearrange and improve the operation of the Wild magnetographs. In particular, the two horizontal intensity magnetographs of that type were oriented to register the east-west and north-south components of the horizontal intensity, as recommended by the international committee.

All of the magnetographs have now been provided with electromagnetic coils for determining their scale values at frequent intervals. These coils are of the types used on the magnetographs designed by Ad. Schmidt for the new magnetic observatory at Seddin.[1] The work of standardizing the magnetometer and the magnetographs has been taken up and the constants for the Wild magnetometer have been determined with sufficient accuracy for the current reduction of the absolute observations. More accurate determinations will result as the new apparatus just received is put into use and the number of observations increases. The temperature and distribution coefficients are being determined from the regular weekly observations, and a higher degree of accuracy will accrue from an increased number of observations.

The scale coefficients of the magnetographs have been accurately determined. Preparations are now being made to obtain the temperature coefficients of these instruments by subjecting them to artificial variations of temperature in an air bath, the temperature of which can be controlled automatically.

An account of the methods and the instruments used in these experiments and a summary of the results obtained are being prepared and will probably appear in the Bulletin of the Mount Weather Observatory.

The tabulation of the hourly values of the magnetic elements from the photographic records has been begun and will be carried forward to such a point that it will only require the application of the temperature correction to obtain the true values.

Action has been taken to secure from the magnetic observatories of the Coast Survey and from a number of foreign observatories data for the investigation of the time relation of the beginning of magnetic disturbances of the different places on the earth, from which it is hoped to obtain results that will throw light on the nature and mode of progression of those disturbances that are believed to proceed from the sun.

SOLAR PHYSICS.

The work in solar physics as conducted at the present time consists in the measurement of the amount and intensity of solar radiation, the degree of absorption of the earth's atmosphere, and the polarization of blue sky light, and in the determination, by means of these data and an empirical formula developed by Prof. H. H. Kimball, of the solar constant or the heat received at a point just outside of the earth's atmosphere. The instrumental equipment includes two Ångström pyrheliometers and a Pickering polarimeter, together with a storage battery, a mil-ammeter, and a rheostat. Values of the solar radiation are obtained, which, with other data, including the

[1] Zeitschrift für Instrumentenkunde, May, 1907, p. 137.

vapor pressure, may make it possible to compute the solar constant and, finally, the amount of absorption by the earth's atmosphere. The work is facilitated by the use of reduction tables and especially by the employment of a diagram that shows the air masses thru which the sun's rays pass at different hours of the day and for different declinations of the sun.

This work was begun at Mount Weather in September, 1907, and observations have been taken every day since, with the result that up to July 1, 1908, thirty determinations of the solar constant had been made. An extra pyrheliometer is used in making comparative readings to detect any changes that may be taking place in the constant of the station instrument. Readings with the Pickering polarimeter have been made on every day, but thus far these have not been reduced.

During the ensuing year it is planned to continue observations along the same lines as heretofore.

SOLAR RADIATION.

Atmospheric conditions of temperature, moisture, and sunshine may be said to control almost completely the growth of vegetation in general.

Observations of temperature and moisture have been made by meteorologists for many years, but measurements of solar radiation have been almost entirely restricted to laboratory investigations, and even then nothing has been attempted on a scale sufficiently comprehensive to show the radiation available during the entire day or during the growing season. Heretofore apparatus capable of giving in reliable form the data required have not been available, and instruments designed to meet the requirements can be used successfully only by observers of exceptional training.

An instrument that promises to give good results and which records continuously the total radiation received from the sky, as well as from the disk of the sun when not obscured, has been procured and will be tested by the Instrument Division to determine its reliability.

The records from this instrument will show day by day the total radiant energy upon each unit of area of the surface of the earth, and such data summarized for different regions should be of value when used in connection with studies of the growth and development of plant life.

SOLAR CONSTANT.

A phase of this problem of the measurement of solar radiation has been the subject of several years' study by Professor Kimball—namely, the determination of the total heat that reaches the outside limits of the earth's atmosphere. It is only within recent years that scientists have been able to demonstrate that the solar radiation is variable. One outcome of the studies conducted at the Weather Bureau has been to make plain the errors of the apparatus heretofore employed in these investigations. At the suggestion of Professor Marvin arrangements have been made to use a special type of electrical pyrheliometer, with which it is hoped to attain greater accuracy and to avoid the deterioration with age that is characteristic of the older apparatus.

STUDY OF APPARATUS.

In July, 1907, a series of comparative readings was obtained from the Ångström pyheliometer and the Smithsonian actinometer. In December following two additional instruments were received from Ångström, the constants to one of which he had determined with care, and in accordance with his suggestion this instrument has been preserved as a standard. In February, 1908, a second series of comparative readings from Ångström and Smithsonian instruments was obtained, and the fact established that the reduction factors for Ångström pyrheliometers change slowly with age. Effort has been made to obtain an instrument not subject to these changes, and an order has been placed for a new pyrheliometer, the essential features of which have been suggested by Professor Marvin.

At present eye readings of the pyrheliometer are made at frequent intervals whenever the sky is free from clouds, and the data obtained are tabulated, so as to show the relative amounts of solar radiation received at different seasons of the year and in different years. It is not possible by this method to obtain continuous records of the quantity of solar radiation received under all sorts of atmospheric conditions. A Callendar recorder, designed for use in connection with a special form of pyrheliometer, is now being tested, and it is hoped that with it the desired continuity of records may be obtained. In its present form the instrument records the radiation received from the entire sky.

NEW FORMULA FOR COMPUTING THE SOLAR CONSTANT.

An equation has been developed by means of which the atmospheric transmissibility for solar energy of different wavelengths may be computed with reasonable accuracy from pyrheliometric observations, most conveniently from observations with the sun from 20° to 30° above the horizon, provided the water-vapor content of the atmosphere at the same time is also known. This formula has been applied to pyrheliometric observations obtained at Washington on 69 different occasions between December 22, 1905, and June 30, 1908, and to observations obtained at Mount Weather on 26 different occasions between September 21, 1907, and June 30, 1908. The mean value of the solar constant as computed for both stations is in close agreement with the mean value obtained by Abbot on Mount Wilson in 1905 and 1906.

The results of instrumental comparisons, the reduced pyrheliometer observations, and the computed values of the solar constant have been published in the Bulletin of the Mount Weather Observatory, Vol. I, parts 2 and 4.

Considerable discrepancies exist in the values of the solar constant computed from observations on different days, and even from observations at Mount Weather and at Washington on the same day. In most cases these are traceable to the unsteadiness of the atmosphere. The formula employed, in common with all formulas with which we are familiar, assumes that atmospheric conditions are uniform during the period of observation, which usually lasts two hours. Such conditions probably do not occur in the eastern part of the United States more than ten or twelve times during the course of the year, and almost never during the summer months. It is therefore hoped that, if the new apparatus ordered proves satisfactory, arrangements can be made to obtain observations at some point in the arid Southwest, where it is believed favorable conditions prevail on a majority of the days thruout the year.

The headquarters for solar radiation investigations were transferred from the Central Office to Mount Weather, Va., on July 1, 1908.

UPPER-AIR OBSERVATIONS AND WEATHER FORECASTS.

In previous years upper-air observations for the study of the forecaster were telegraphed from Mount Weather to Washington at irregular intervals. During the year that ended June 30, 1908, they were telegraphed daily. The character and special value of these observations in their application to practical weather forecasting and the manner of utilizing them are illustrated by the following extracts from the general forecasts issued at Washington:

May 1, 1908.—The cold weather of the last few days has reached its climax, and will doubtless be followed within the next few days by considerably higher temperatures east of the Mississippi. The kite observations to-day at Mount Weather at an elevation of about a mile above the station showed a temperature of only 10° above zero, or a fall of 25° in the last twenty-four hours. This would seem to indicate a slow rise on the surface during the next twenty-four hours.

May 6, 1908.—Since the beginning of the present rainy spell it has been impossible to get the kites at Mount Weather more than 3,200 feet above the mountain, thus indicating the existence at that level of a considerable stratum of calm or light winds and a temporary suspension of the characteristic west-east movement of the upper air in these latitudes. This is the probable explanation of the failure of the Mississippi Valley storm to advance eastward. To-night's reports show, however, a well-developed storm center in southern Indiana, with a tendency to move northeastward by way of the St. Lawrence Valley. Should it move as indicated, the great cloud blanket that has covered the country east of the Mississippi since Monday last will be lifted by Friday morning, and higher temperatures will prevail.

May 18, 1908.—The kite flights at Mount Weather during the last few days have reached only small elevations above the mountains, thus indicating, as on a previous occasion during the month, the existence of a considerable stratum of calm or light winds about 2,000 feet above the mountains, thru which the kites can not pass. The surface winds in both cases were from the east.

A return of the stagnant conditions that prevailed during the latter half of May was noted on June 3. In each instance unsettled and rainy weather was experienced over the eastern portion of the country and the surface winds were from the eastern quadrants.

June 15, 1908.—The kite flight at Mount Weather to-day reached an altitude of nearly 2 miles above the station, at which elevation the temperature was 31°, while at the surface it was 65°. High northwest winds and heavy rain followed the flight.

The rains and cooler weather that reached the Atlantic States on this date were in accord with a forecast issued June 9.

June 22, 1908.—To-day the kite at Mount Weather past thru a warm warm stratum of air at an elevation of 1,500 feet above the station, where the temperature was 75°, or 7° higher than at the surface. The warm air did not extend much above 1,500 feet, and from that elevation up to 5,700 feet above the station the temperature fell 15°.

On this date a warm wave covered the country east of the Mississippi. On the following date, June 23, there was not sufficient wind to fly a kite and it became necessary to use a captive balloon. The latter showed an almost uniform decrease in temperature from 84° at the surface to 61° at an elevation of 7,800 feet.

June 30, 1908.—During the kite flight at Mount Weather to-day an altitude of 16,300 feet was reached, at which elevation the temperature was 20°, while at the surface it was 74°, with westerly winds.

The weather map to-night is of the hot-weather type—high pressure in the southeast and low over the north and northwest. As a consequence temperatures are much above the seasonal average over the entire country east of the Rocky Mountains, except where local thunderstorms have afforded temporary relief.

July 3, 1908.—The vigorous circulation of the air in the higher levels above Mount Weather that characterized the closing days of June has now given way to stagnant conditions that make it necessary to use captive balloons instead of kites in sounding the air. The ascension to-day showed a uniform fall in temperature from 76° at the surface to 58° at an altitude of 6,400 feet above sea-level.

July 13, 1908.—The kite flights on Mount Weather to-day showed, as on a previous occasion under similar conditions, a marked temperature inversion about 1,500 feet above the earth's surface. At that level it would seem that nocturnal radiation is not effective in lowering the night temperature as on the earth's surface.

The outlook is for slowly moderating temperature over the eastern half of the country during the next two days. There are no present indications of another period of excessive heat.

July 17, 1908.—Since the breaking up of the warm spell the upper air currents have been unusually active. On the 15th the kites at Mount Weather broke away in high winds at an elevation of 8,400 feet above sea-level. On the 16th an elevation of over 17,000 feet was reached, with brisk northwesterly winds and a temperature of 15° above zero. At the surface the temperature was 65°.

On July 22 a zone of light variable winds was again shown at an altitude of about 1,000 feet above the station, the first condition of this character observed in about ten days. A captive balloon that past thru the calm zone indicated the prevalence of westerly winds at an altitude of 1 mile above the station and a temperature of 57° as compared to 77° at the surface. As in previous cases noted, the presence of a stratum of light winds or calm at an elevation of 1,000 to 1,500 feet above the station attended generally unsettled and rainy weather over the eastern portion of the United States.

July 30, 1908.—Hitherto the kite flights at Mount Weather have uniformly shown that easterly winds over that region are quite shallow, none of them extending more than a mile above the mountain. On Thursday, for the first time, at an altitude of about 2 miles above the station, rather strong easterly winds were found, thus indicating a suspension of the ordinary west to east drift in these latitudes.

At this time a storm that had moved slowly northward from the subtropical region of the Atlantic was central near the North Carolina coast, with reported barometer 29.22 inches at Wilmington. The unusually strong and high drift of easterly winds referred to was doubtless due to the exceptional strength of the air currents in the northern quadrants of this storm. The high winds that followed the northward movement of the storm center carried away three kites at an altitude of more than 3 miles on August 1.

August 20, 1908.—The kite flights on the 18th, 19th, and 20th reached an altitude of about 3 miles above sea-level. The temperature at that height on the 18th was 30°, falling on the 19th to 28°, and on the 20th to 24°. The fall at the upper level was felt nearly forty-eight hours before it reached the surface.

August 27, 1908.—On the 25th the kites at Mount Weather past into a dense layer of cloud and fog, which enveloped the mountain and probably extended more than 6,000 feet above it. The air temperature at the upper level was nearly the same as at the surface. The winds were north-northeast at the surface, shifting to northeast aloft, such as would be required with a storm center off the south Atlantic coast.

Beginning August 23, a barometric depression had occupied the Gulf States, and on the 25th the center of disturbance was over the east Gulf States and the low area extended thence over the south Atlantic coast. To the north and northeast was an area of high barometer. This distribution of pressure extending over a two or three-day period caused a prolonged drift of northeasterly winds over the Middle Atlantic States, and, as shown by the Mount Weather observations, equalized temperatures in the air currents to an elevation of more than 6,000 feet. This was a period of exceptionally heavy rains that gradually extended from Georgia northward to New England.

The daily observations that have been secured during the past year at a nearly uniform altitude of about 1 mile above the Mount Weather station and the occasional surroundings of the atmosphere to much greater heights have been of particular interest to the forecaster. A study of data that have been obtained, and that will be secured by improved apparatus, will undoubtedly reveal elements of cause in the practically unexplored regions of the upper atmosphere that will account for many phases of weather and climate that observations taken at the surface of the earth do not indicate or presage.

FORECAST AND WARNINGS.

Attention has been given during the past year to isobaric charts based upon telegraphic reports received daily from selected stations thruout the Northern Hemisphere. Forecasts for periods of about a week in advance were begun experimentally, and during the last three months of the year they were prepared for publication. The following of these forecasts are presented for the reason that they dealt with notable abnormal conditions:

WASHINGTON, D. C., *Saturday, April 18, 1908.*

Forecast for the week beginning Sunday, April 19, 1908.

For the States of the Missouri, extreme upper Mississippi, and Red River of the North valleys, where little or no rain has fallen, a season of showery weather will be inaugurated by the middle of the week. In the Gulf States and lower Mississippi Valley the excessive rains of the past week will give way to a period of more settled weather.

Heavy showers set in over the north-central districts referred to during the night of Wednesday, April 22, and precipitation continued in that region during the following three or four days. In the South Central States the prolonged period of rain ended on the 21st.

The Cheyenne Tribune of May 4, 1908, had the following editorial concerning the forecast of May 2 for the following week:

The weather man down at Washington has made an excellent guess. Saturday he gave to the Associated Press the following:

"The rains of the week beginning Sunday, May 3, will cover the principal agricultural districts from Canada to the Gulf of Mexico. From May 3 to 5 an area of general rains will advance from the Pacific to the Atlantic coasts, reaching the Atlantic coast Monday night or Tuesday * * *."

The storm Cheyenne is now enjoying arrived very promptly on schedule, and is worth more to Laramie County than can be measured in dollars and cents. The precipitation is probably general over Wyoming.

The rains referred to broke a drought in Wyoming and eastern Colorado that was rapidly becoming serious.

On Monday, June 15, the following was issued:

The period of persistent heavy rains of the last two weeks that have caused destructive floods in the Middle Western States will end by Thursday. Temperature will rise in the Plains States and central valleys after Tuesday and the warmer weather will reach the Atlantic States about the close of the week. Next week will open warm over the eastern portion of the country.

The heavy rains of the Middle Western States practically ceased Thursday. Following the termination of the rain period the first well-defined warm wave of the season set in over interior districts and extended to the Atlantic coast by the close of the week. A forecast dealing especially with this warm wave was issued on the morning of Monday, the 22d:

The warm wave that now covers the country generally east of the Rocky Mountains will break over the Plains States Tuesday, over the Mississippi Valley and the western Lake region Wednesday, in the Ohio Valley and eastern Lake region Wednesday night, and in the Atlantic States Thursday. Local rains and thunderstorms will attend the advent of the cooler weather in the several sections named. Moderate temperature will be experienced over the eastern portion of the country during the closing days of the week.

This forecast, like preceding ones, was closely verified. The value of accurate forecasts for this period to agricultural and business interests can not be measured, and the success that has attended the experimental and published forecasts will justify this office in making weekly forecasts a regular feature of its work. Their inauguration will mark a most important advance in the practical application of meteorological science. Using as a basis of calculation isobaric lines of the Northern Hemisphere, forecasts may, on occasions, be safely made for periods greater than one week. The next advance in the art of forecasting will be marked by a still further extension of the forecast period.

All severe storms on the American coasts and lakes and severe cold waves and frosts that visited any portion of the United States during the year were successfully forecast. No important storms of tropical origin visited the United States coasts. The following dispatch from Kingston, Island of St. Vincent, British West Indies, dated September 20, 1907, indicates the character of disturbances that occur in that section during the prevalence of low barometric pressure over the tropical regions of the oceans:

Recent advices from the Weather Bureau at Washington were verified in a remarkable manner. A disturbance east of the Windward Islands, which had been announced as probable, developed yesterday into a thunderstorm of great severity. Exceedingly low thunder clouds hung over St. Vincent, and the lightning was fearfully vivid. Several casualties occurred. Similar storms have been experienced in the northern islands.

The association of upper-air observations made at Mount Weather with the practical work of weather forecasting is receiving special attention, and progress is being made in determining the relation of cause and effect that exists between conditions observed in the upper strata and certain types of normal and abnormal weather.

INSTRUMENTS.

For many years the operations of the Instrument Division have been governed by a fixt policy of slowly bringing the instrument equipment of all regular stations up to a certain uniform and high standard. This work was practically completed a year ago, as stated in my last annual report.

No new stations were established during the year closed June 30, 1908, and the ordinary resources of the Instrument Division thus became available for the betterment of station outfits that had been in service for many years.

Partial equipments consisting of barometers, thermometers, rain-gages, and shelters, have been issued to special observers at Greenville, Me.; Leadville, Colo.; Wallace, Idaho.; Jackson, Miss.; Sitka, Alaska, and Marshfield and Siskiyou, Oreg., from each of which daily telegraphic reports are rendered at the nominal compensation of $25 per month.

SEISMOGRAPH AND EARTHQUAKE RECORDS.

The seismographic records were constantly maintained during the year. A new instrument of high magnification (120 times), designed by Professor Marvin, was installed in November and has since been in successful operation. A detailed description of this seismograph was published in the MONTHLY WEATHER REVIEW for November, 1907.

In the latter part of the year a seismograph of European manufacture for recording vertical motion was purchased and temporarily installed. This instrument, however, is so seriously disturbed in its action by variations of temperature, air currents, etc., that its installation requires exceptional surroundings, which are not now available. It is hoped Congress will favor the extension of seismological work along the lines indicated in my last annual report. In the meantime these important studies are restricted to the simple maintenance of the daily records from the instruments now installed.

NEW WORK.

The work of inventing new apparatus to meet the ever-increasing demands of the Bureau may be summarized under the following items:

(1) *Chart and instrument kiosk.*—A suitable means of taking meteorological observations, especially of temperature and humidity, near the street levels, and thus representing more nearly the conditions experienced by pedestrians and the public generally, has long been needed. To meet this need it seemed practicable to expose instruments, accompanied by climatic charts, weather maps, and forecast cards, in a shelter of appropriate design, located at some favorable point or points in the business and news centers of every large city. Prof. C. F. Marvin, in charge of the Instrument Division, was instructed to work out the details of such a scheme. The problem involved not only the design for the kiosh itself, which must provide proper exposure for the instruments and charts and protect them from molestation, but also new instruments of a construction adapted to satisfy conditions. The instruments comprise special forms of maximum and minimum thermometers, air thermometer, hair hygrometer, thermograph, and a special type of tipping-bucket rain-gage with dial indicator. All of these have been successfully devised by Professor Marvin.

(2) *Recording hygrometers for stations.*—The moisture content of the air constitutes one of the most important meteorologi cal elements requiring observation, yet its automatic registration in an accurate manner has thus far baffled the genius of inventors. An American manufacturer has made important improvements to an instrument for this purpose. A few have been tried at stations selected for the purpose of securing the most satisfactory tests. Gratifying results have been obtained, but a longer test is necessary.

(3) *Tele-thermoscopes.*—The local offices of the Weather Bureau in large cities are called upon by telephone or otherwise many times daily for temperature data, especially during periods of exceptional weather conditions, and for many years, a type of instrument has been in demand that would record or indicate in the main office room the true temperature outside. In the absence of such an instrument observers have been obliged to make frequent trips to the roof, which is often at a

considerable distance. Within the past year a type of apparatus capable of showing but not recording the air temperature has been introduced to meet these needs; it is of such a character that it gives promise of meeting the exacting requirements of the Bureau with regard to accuracy. The thermometer is a protected coil of wire, the electrical resistance of which varies with temperature. The indicator, which is located in the office, is a device that determines the electrical resistance of the coil and indicates the corresponding temperature. Ten of these instruments have been installed.

(4) *Automatic river-gages.*—Among the newer types of instruments that have been introduced in recent years, mention has been made in previous reports of automatic gages for recording or indicating river stages. The installation of one of these at Pittsburg was completed during the past year, and work was begun on the mounting of a similar gage at Cincinnati, Ohio, on the north pier of the Covington and Cincinnati suspension bridge. The introduction of this gage will give us what we have been unable to obtain heretofore, namely, the extreme flood stages of the river. The extreme range of the Ohio River at this points amounts practically to about 75 feet. The new gage will automatically indicate in the office of the observer, no matter what its distance from the river, all stages above 18 feet.

RIVER AND FLOOD SERVICE.

The months from February to June, inclusive, of the present year were characterized by frequent floods, some of them of grave character, taxing to the utmost the resources of the Weather Bureau to deal successfully with them.

The Ohio Valley was the chief sufferer, with floods of marked character during each of the four months from February to May, inclusive. The floods of May were not limited to the Ohio River, but extended thruout the entire Mississippi watershed above the mouth of the Ohio River. In the month of June general and destructive floods occurred over the same watershed, except the Ohio River portion, and the fortunate failure of the Ohio simultaneously to be in flood stage prevented the greatest flood in the history of the lower Mississippi River. As it was, the river at New Orleans reached a stage of 20 feet on June 19 and 22, only 0.4 foot below the great high-water stage of April 6 and 7, 1903. At the close of the year the river stood at 19.6 feet on the gage, having been above the flood stage continuously since March 9.

The most destructive floods of the year occurred in the Red and the lower Arkansas rivers and their tributaries in the State of Oklahoma, and in the Trinity and Brazos rivers of Texas, the losses in Texas alone amounting to not less than $5,000,000.

These floods were forecast with the same accuracy that attended those of former years, and in some instances with an exactness much beyond that ever before attained. Particular attention is invited to the work along the Red and lower Mississippi rivers, where the warnings, given in detail two weeks in advance, were so exact as to leave practically no percentage of error. Numerous newspaper editorials and several resolutions of thanks from representative bodies testified to the public appreciation of the work of the Weather Bureau.

With each succeeding year the development of agricultural operations and the extension of business interests, more or less dependent on river stages, necessitate some broadening of the field of activity of the River and Flood Service, and during the present year new work has been undertaken as follows:

(1) The establishment of a continuous flood-warning service, operating day and night in times of flood, in that portion of the State of West Virginia bordering on the Ohio River.

(2) The establishment of a new river district center at Binghamton, N. Y., with territory comprising that portion of the watershed of the Susquehanna River at and above Binghamton. This territory was formerly a portion of the Harrisburg, Pa., district.

(3) The opening of new river stations in the watershed of the upper Cumberland River, in the interest of navigation and the lumber industries.

(4) The opening of several new stations at scattered places thruout the country, in order to secure increased efficiency in the flood-warning service.

Realizing the fact that the art of river forecasting is dependent upon the intelligent use of data of diverse kinds, and that the exigencies of the Weather Bureau service frequently render it impossible for officials in charge of river districts to systematize and preserve for future use their knowledge of the regimen of the rivers in their districts, the river and flood branch of the Central Office at Washington has begun, in cooperation with the district officials, an exhaustive study of the problem. The Ohio River and its principal tributaries as far south as Cincinnati, Ohio, have thus far been studied and the results in elaborate form have been transmitted to the officials in charge of the various districts for actual use in river forecasting. It is hoped that the scheme for the entire Ohio River, and possibly a portion of one for the Mississippi River, can be completed within another year. The work is necessarily slow, as it involves the discussion of a large amount of data.

The new field work contemplated during the coming year is largely suggested by the flood problems of the present year, as well as by requests for increased service from Members of Congress, citizens, corporations, and associations of various kinds. Should our resources permit, it is proposed to introduce flood-warning service along the Oklahoma tributaries of the Arkansas River, and to extend somewhat the present service on the Red and Neosho rivers, and possibly the upper Arkansas River. In connection with the latter project, it may become necessary to establish a new river district center at Wichita, Kans. Request has also been made for additional service along the upper Missouri River and its tributaries, and the matter will be given attention during the coming low-water season.

No definite suggestions can be made at this time regarding proposed work during the fiscal year ending June 30, 1910. It may be possible by that time to take up the question of river service over the Yukon River watershed in the interest of navigation, and also the expansion of the service that will be necessary on the Ohio and lower Mississippi rivers in order to meet the requirements of inland water transportation.

CLIMATOLOGICAL DIVISION.

During the year ended June 30, 1908, the Climatological Division was charged with (1) the collection and publication of climatological data, and (2) the distribution of forecasts and special warnings. Under the first-named heading may be classed:

(a) Cooperative stations, of which there are more than 3,700.

(b) Cotton, corn and wheat, and sugar and rice region stations, and the publication of the daily bulletins (Forms Nos. 1045 and 1046–Met'l) at district centers and other selected Weather Bureau stations for the period from April to October.

(c) The monthly and weekly publications of the several sections of the climatological service, including the monthly snowfall bulletins of the States of the Rocky Mountain and Plateau regions for the period from December to March.

(d) The preparation of the national weekly and monthly weather bulletins, and the weekly snow and ice bulletins issued during the winter months.

COOPERATIVE STATIONS.

At the close of the year there were 3,761 stations of this class in operation, an increase of 77 over the number in opera-

tion at the end of the preceding year. Most of the newly established stations are in the semiarid regions of the West, special efforts having been made to place stations at the higher altitudes of the drainage basins of the streams whose waters are used in irrigating. Two hundred and sixty-three cooperative stations, the majority of which were in the eastern portions of the country, were for various reasons discontinued. During the year 237 stations were visited by section directors for the purpose of inspection. The number of stations inspected was considerably greater than during the previous year.

COTTON, CORN AND WHEAT, AND SUGAR AND RICE REGION STATIONS.

The number of cotton region stations at the close of the year was 143, or 1 less than at the close of the preceding year, 2 stations having been discontinued and 1 established. There are 137 corn and wheat region stations, 4 more than at the close of the year ended on June 30, 1907, 7 having been established and 3 discontinued during the year of 1907–8.

CLIMATOLOGICAL PUBLICATIONS.

The publications of the 44 section centers of the climatological service have continued without change. The monthly reports of all the sections have been issued with promptness, the majority making their appearance before the 20th of the month succeeding that to which they pertain. With the installation of a number of additional printing plants, the number of sections having their reports printed by contract has been reduced to 2, namely, Idaho and Hawaii, against 7 at the close of the previous year. The average date of issue of the annual climatological reports was earlier than in the year before. The weekly weather bulletins issued during the crop-growing season have been regularly published by all the sections, including Porto Rico and Hawaii. A reduction in the edition of these bulletins is noted, the total number being more than 3,000 below that of the previous year.

The foregoing table shows for each section the number of cooperative observers, the number of weather correspondents, and the editions of the weekly weather bulletins and monthly climatological reports.

Cooperative observers, weather correspondents, and edition of climatological publications.

Section.	Number of—		Publications issued.	
	Cooperative observers.	Weather correspondents.	Weekly bulletins.	Monthly climatological reports.
Alabama	38	128	500	500
Alaska	45	0	0	0
Arizona	80	55	700	700
Arkansas	65	58	525	665
California	350	50	500	700
Colorado	95	42	300	700
Florida	60	75	750	475
Georgia	42	150	650	625
Hawaii	151	53	396	458
Idaho	65	76	600	450
Illinois	90	90	780	430
Indiana	58	140	650	725
Iowa	121	700	1,900	1,800
Kansas	93	91	1,500	1,250
Kentucky	39	39	350	325
Louisiana	42	75	450	700
Maryland and Delaware	51	60	300	325
Michigan	115	124	389	750
Minnesota	81	42	600	425
Mississippi	63	85	400	715
Missouri	78	110	368	381
Montana	81	85	600	600
Nebraska	140	404	760	585
Nevada	40	42	150	300
New England	150	55	350	700
New Jersey	51	55	400	325
New Mexico	78	70	450	870
New York	123	117	900	825
North Carolina	66	114	420	900
North Dakota	80	50	500	550
Ohio	96	109	650	575
Oklahoma	70	190	700	650
Oregon	93	93	300	540
Pennsylvania	87	65	320	600
Porto Rico	45	33	182	375
South Carolina	32	47	480	430
South Dakota	65	98	575	637
Tennessee	50	88	250	450
Texas	148	150	800	900
Utah	83	154	500	600
Virginia	54	94	325	950
Washington	85	45	600	850
West Virginia	55	65	900	500
Wisconsin	84	84	350	500
Wyoming	73	20	275	350
Yellowstone National Park	10	0	0	0
Total	3,761	4,570	24,345	27,661

DISTRIBUTION OF WEATHER FORECASTS AND SPECIAL WARNINGS.

Diligent efforts have been made to increase the distribution along all lines, but, as in the previous year, the principal part of this work has been directed toward the dissemination of forecasts thru the medium of the telephone companies, and they have responded almost unanimously to the invitation to cooperate for the benefit of their subscribers. During the year several States of the Middle West and on the Pacific slope were canvassed, and as a result a large number of telephone companies in those States are now cooperating with the Bureau in this important work.

Distribution of daily forecasts and special and emergency warnings.

State or Territory.	At Government expense.			Without expense to United States by—				
	Forecasts and special warnings.	Special warnings only.	Emergency warnings.	Mail.	Rural free delivery.	Telephone.	Railroad train service.	Railroad telegraph.
Alabama	33	2	139	1,124	661	4,715	0	96
Arizona	8	0	0	152	0	5,911	0	0
Arkansas	27	7	102	636	666	15,837	0	15
California	124	12	0	1,379	4,086	52,986	0	9
Colorado	19	60	39	396	1,748	32,830	0	0
Connecticut	16	0	49	1,401	50	71,292	131	0
Delaware	10	0	0	95	1,025	4,865	0	30
District of Columbia	0	0	0	1,419	0	5,700	0	1
Florida	30	131	32	1,068	263	5,329	0	58
Georgia	43	33	241	1,782	1,307	21,197	0	214
Idaho	23	0	0	533	255	13,559	0	0
Illinois	121	0	468	4,301	2,808	457,052	0	17
Indiana	114	1	208	2,117	1,935	154,279	0	76
Iowa	143	6	400	1,996	3,522	107,484	25	0
Kansas	87	1	186	1,266	1,915	202,415	0	15
Kentucky	40	34	96	1,648	720	25,038	0	1
Louisiana	36	36	61	680	340	2,224	0	9
Maine	16	1	40	1,009	877	12,146	0	0
Maryland	25	4	42	2,131	1,096	6,546	0	80
Massachusetts	23	10	63	3,262	210	8,950	77	0
Michigan	86	3	379	5,484	373	408,759	279	239
Minnesota	83	5	196	2,417	4,300	144,601	0	18
Mississippi	41	7	118	1,061	958	35,555	0	6
Missouri	37	0	240	3,318	2,231	306,329	0	26
Montana	13	19	18	441	50	10,311	0	0
Nebraska	82	2	221	1,170	406	155,465	0	0
Nevada	6	0	0	64	0	413	0	0
New Hampshire	20	0	34	794	1,429	2,285	14	0
New Jersey	30	18	45	1,218	0	7,215	0	195
New Mexico	8	0	0	125	0	5,361	0	17
New York	143	46	365	7,778	2,392	272,332	176	143
North Carolina	74	14	189	712	2,795	24,421	0	0
North Dakota	21	0	99	194	2,009	31,616	0	0
Ohio	100	96	312	6,378	1,474	500,909	24	26
Oklahoma	36	1	17	661	1,151	7,313	0	116
Oregon	11	0	0	482	435	5,457	0	0
Pennsylvania	78	11	367	4,088	1,718	153,210	1	534
Rhode Island	2	0	12	471	0	898	12	0
South Carolina	35	8	109	914	672	3,990	0	40
South Dakota	61	13	77	734	415	31,221	0	0
Tennessee	36	5	291	1,391	1,676	16,811	0	3
Texas	133	49	240	1,158	2,961	52,651	0	60
Utah	9	35	0	387	1,041	32,333	0	0
Vermont	16	0	46	471	466	10,428	12	8
Virginia	61	3	96	1,512	1,848	29,535	101	71
Washington	26	0	0	777	1,421	2,600	0	0
West Virginia	28	7	55	906	7	29,049	0	16
Wisconsin	116	7	298	2,542	2,296	54,809	0	0
Wyoming	5	3	8	111	0	6,835	0	0
Total	2,334	690	5,998	76,154	58,008	3,553,067	852	2,139

One of the largest telephone companies operating in the Southern States, which had heretofore declined to take up the work of distribution, has fallen into line and is now giving its subscribers the benefit of the daily forecasts, thru a

large number of exchanges, particularly in the States of Mississippi and Tennessee.

In the States of the Middle West the telephone is largely used for transmitting forecasts, and the weather information is much appreciated. The officers of the companies state that the number of calls that come into "central" daily for the weather reports is surprising. They say that it is an advantage to them to have the opportunity of distributing the information free, as such action aids in securing more subscribers. Some officials, in fact, are enthusiastic in their commendation. A special correspondent of the New York Evening Post writes from Kansas City, Mo., as follows:

> Little wonder that every day's weather predictions are awaited with interest. Early in the morning in the central telephone stations of the grain counties the calls come in to know "What does the weather man say?" The farmers' lines are kept busy answering these calls until nearly noon. So insistent is the demand for this news that many of the companies send out a general call for all subscribers at 9 o'clock, and read the bulletins.

The greater portion of the telephone companies are now publishing in some prominent place in their directories the following notice:

> Subscribers of this company may obtain the daily forecasts and special warnings of the Weather Bureau of the United States Department of Agriculture from their respective exchanges after 11 a. m., eastern time. These forecasts usually cover the thirty-six hour period ending at 8 p. m. of the following day.

The foregoing table gives, in detail, the distribution of forecasts and special warnings for the various States and Territories.

MARINE DIVISION.

This division collects meteorological information pertaining to the oceans from naval and merchant marine vessels, plots the data (pressure, temperature, wind, and weather) on daily synoptic charts for study and for the preparation of monthly summary charts, and compiles in tabular form meteorological data for the use of the Hydrographic Office of the Navy in the preparation of the Pilot Charts.

The normal pressure and temperature inset charts, tables showing the percentage of fog and gales, and wind roses showing the direction and force of the prevailing winds, are printed monthly for all coast stations and each 5° square of latitude and longitude on the Pilot Charts of the North Atlantic and North Pacific oceans.

The metorological data are obtained thru a system of cooperation on the part of vessel owners and captains and the United States naval vessels, the Bureau furnishing in lieu of other compensation such available publications as may be of service. During the last year 1,608 vessels, hailing from every port and flying the flag of every nation, cooperated with this Bureau. Meteorological reports and publications were distributed to all such cooperating vessels, to local Weather Bureau offices and to American consulates. A number of the forms and charts used are kept on hand at local stations and American consulates for filling requests.

Twenty-five local Weather Bureau offices are equipped to assist in the marine meteorological work. The stations at Portland (Me.), Boston, New York, Philadelphia, Baltimore, Norfolk, Wilmington, Charleston, Savannah, Jacksonville, Tacoma, Seattle, Portland (Oreg.), San Francisco, San Diego, Honolulu, and Washington are supplied with marine barometers.

PILOT CHART, NORTH PACIFIC OCEAN.

Beginning with the month of January, 1908, the meteorological data for this chart have been entirely revised, the averages or normals for pressure, temperature, wind (direction and force), percentages of gales, trade-wind limits, and storm tracks being given. These data have been computed for each 5° square of latitude and longitude, and the result of this work is published on the Pilot Chart issued by the Hydrographic Office, Navy Department.

PILOT CHART, NORTH ATLANTIC OCEAN.

The revision of the meteorological data for this chart commenced with the month of July, 1908, and has been continued for each succeeding month.

A chart giving the prevailing winds and calms, with gale percentages, is furnished to the Hydrographic Office forty days in advance of the date of publication, while the inset chart (pressure and temperature), trade-wind limits, storm tracks, percentage of gales and fog, and a statement of average conditions of wind and weather, are delivered thirty-five days in advance. It will be necessary to make a revision of the wind-rose data, prevailing direction and force of the wind, for the North Atlantic and North Pacific oceans for the months prior to August.

INDIAN OCEAN.

All meteorological data received from vessels sailing this ocean are dispatched every six months to Simla, India, where they are copied for the use of the Indian meteorological department and then returned to this Bureau.

FOG.

At the request of Mr. James White, geographer, Department of the Interior, Ottawa, Canada, made on March 24, 1908, a chart for each month, showing the frequency of fog in the Gulf of St. Lawrence and on the great circle route between Belle Isle and the north of Ireland, was prepared and furnished for the period 1901–1907.

WIRELESS TELEGRAPHIC WEATHER SERVICE.

On September 20, 1907, the Marconi Wireless Telegraph Company, and the foreign and American agents of the vessels cooperating with this Bureau, by transmitting meteorological observations made at sea, were informed that this service is suspended for the present.

The official at San Francisco has arranged thru this Bureau and the Quartermaster-General of the Army to have the Army transports plying between that port and Manila send wireless messages containing weather reports to that station. This work will be taken up by the transports as rapidly as wireless equipments are installed. It is the purpose to utilize the reports in forecasting the weather conditions for the coast.

The official at Portland, Oreg., has completed arrangements with Mr. W. J. Smith, manager of the Marine Transportation Company, to receive each morning and evening observations of pressure, temperature, wind, and weather from the following ships plying between Portland, Seattle, Alaskan ports, and San Francisco, viz, *Humboldt*, *President*, *Governor*, *Rose City*, *G. W. Elder*, *Roanoke*, and *City of Pueblo*.

VESSEL-REPORTING SERVICE.

In addition to the meteorological work, the officials in charge of the stations at Block Island, Cape Henry, Jupiter, Sand Key, Southeast Farallon Island, North Head, and Tatoosh Island are required to report all passing vessels, wrecks, marine disasters, and other casualties, and transmit all communications between masters, owners, underwriters, and others interested. The stations at Cape Henry, Jupiter, and Sand Key are equipped for signaling and receiving messages by the international code and for transmitting by telegraph all messages received from passing vessels. Sand Key is also prepared to receive and transmit messages at night by flash-light signals. During the last fiscal year these stations received, and transmitted to the vessel owners and others, 24,319 messages. During this time but two complaints were received, and these upon investigation proved unfounded. The Cape Henry station reported the passing of 17,624 vessels without an error being charged to it. The work done at this station was highly commended by the Maritime Exchange of New City and by Commander B. M. Berry, commandant of the navy-yard at Norfolk.

LIBRARY.

Attention is called to the fact that the Weather Bureau has gradually collected a meteorological library that is probably unrivaled thruout the world. The accessioned books and pamphlets number about 28,000, including nearly complete files of the publications of all the meteorological services and independent observatories of the world (including the foreign daily weather maps); files of all scientific journals that devote more or less attention to meteorology, and a large collection of meteorological and physical memoirs, text-books, and reference books. Every effort is made to obtain promptly, by gift, exchange, or purchase, a copy of each new publication bearing on meteorology. Current catalogs and bibliographies are carefully searched for the titles of such publications, and an extensive correspondence is maintained with authors and publishers.

All works in the library are fully catalogued by authors, and about half (comprising all the additions of recent years) are also catalogued by subjects. A very important part of the work of the library consists in cataloging, under both author and subject, the meteorological articles contained in the current numbers of nearly a hundred scientific periodicals, including the transactions and proceedings of societies. This task is justified by the value of the bibliography that is thus accumulating, and that is now more frequently consulted than the catalog of books.

At least two-thirds of the publications received in the library are in foreign languages, in about the following order of frequency: German, French, Spanish, Italian, Russian, Dutch, Portuguese, Roumanian, Swedish, Dano-Norwegian, Magyar, Polish, Czech, Finnish, Japanese.

In addition to the general library of the central office, the Bureau maintains small libraries at 191 stations. All of these libraries are under the supervision of the library at Washington, which purchases and issues all books for stations. During the past year there has been a marked increase in the number of highly technical works issued to stations, including the more important works in foreign languages. This applies especially to the stations at which educational work is carried on and to the research observatory at Mount Weather. The latter now has the nucleus of an excellent meteorological and physical library, and receives a large list of scientific periodicals.

The library prepares for each number of the MONTHLY WEATHER REVIEW a list of current papers bearing on meteorology and seismology, a list of recent additions to the library, and a column of meteorological news, notes, and abstracts. The duties of the supervising examiner, referred to elsewhere, form a considerable part of the work of the librarian.

During the past year the librarian, Mr. H. H. Kimball, has been occupied with important researches on solar radiation, and most of the duties of librarian have been performed by the assistant librarian, Mr. C. F. Talman, who also assumed the duties of supervising examiner on May 22, 1908, and became librarian by promotion on July 1, 1908.

EXAMINATIONS FOR PROMOTION.

The transfer of the examination in essay writing from the first to the second group of examinations, referred to in my last report, has made possible the advancement of many of the younger employees who would otherwise have been retained for an indefinite time in the lowest grades. The ability to write a satisfactory essay, conforming to the rules of good taste as well as grammar, does not depend upon the study of a text-book, but is a question of general education and culture. This examination is too severe a test to impose upon the younger men, whose duties are generally performed in comparative obscurity, under the supervision of others, but is an excellent means of ascertaining the fitness of employees to fill the more important and independent positions.

The total number of examination papers received during the year was 236, as compared with 158 during the preceding year. Following is the record in detail:

Number of examination papers received.

Subject.	1907.		1908.		Total.	Past.	Failed.
	Aug.	Nov.	Feb.	May.			
English grammar	4	8	13	12	37	30	7
Arithmetic	7	9	8	16	40	33	7
Elementary meteorology	6	10	5	13	34	30	4
Algebra	4	7	5	10	26	15	11
Physics	3	2	6	9	20	19	1
Trigonometry	3	5	5	5	18	15	3
Essay writing	3	1	7	6	17	13	4
Astronomy	1	2	8	4	15	12	3
Plant physiology	2	5	4	6	17	16	1
Advanced meteorology	2	2	4	4	12	12	0
Total	35	51	65	85	236	195	41

METEOROLOGICAL RECORDS.

The regular work of the Division of Meteorological Records has been carried on in the usual way thruout the year. It consists of checking the meteorological reports and discussing the same, and preparing reports for publication in the MONTHLY WEATHER REVIEW and the Annual Report of the Chief of Bureau. Nearly 2,000 letters of inquiry on various topics received from the public have been answered, the matter furnished including many certificates of official data for use in the courts. A new series of climatological papers is being prepared, in which the records of precipitation, temperature, dates of the first and last killing frosts, and prevailing wind directions are collected, the precipitation tables including all available data since the year 1871. These reviews are made comprehensive for small sections of the United States, which it is intended gradually to cover in this manner. The papers will be of value to agriculturists, engineers requiring data on water resources, and other citizens who seek information regarding the climate of the several sections.

WATER RESOURCES.

A demand for a better knowledge of the water resources of the United States has become so urgent as to make it advisable to put forth special efforts to supply the necessary data to the public. In the arid and semiarid regions of the West these consist primarily in securing the amount of precipitation from rain and snow in the high levels of the mountains, from which are derived the waters that are used in the storage basins and the irrigation projects now undergoing rapid development. It is a difficult problem to secure regular and accurate observations of the amount of snowfall in the remote regions of the mountains where there are very few inhabitants, but a special effort will be made by the Weather Bureau to extend the range of observations into the high levels of the mountains. A plan has been perfected to cooperate with the Forest Service of the Department in securing these observations. The field work of that Service is of such a nature as to render the cooperation of its officers of value in executing this extension of meteorological observations.

The action of the forests on the conservation of the water resources of the West has so many features of a strictly meteorological character in connection with it, that it seems desirable to cooperate with the Forest Service in the scientific problems which arise in this connection. The Forest Service is planning to establish several high-grade laboratory stations for the study of such problems, and the meteorological conditions in relation to precipitation, evaporation, and the storage of water will have an important place in its program. The Weather Bureau proposes to supply the necessary meteorological apparatus and give what assistance it can of a more technical nature regarding the problems under consideration

It is furthermore proposed to cooperate with the Bureau of Plant Industry in determining the locations of habitats most favorable for the growth of valuable plants, as the date or fig, and other selected types, in the arid and semiarid regions of the West. It will be an economical plan to determine the exact meteorological conditions in selected places, where it is proposed to try the several types of plant life, in order that suitable information may be obtained before undergoing the expense of plant cultivation. A small amount of preliminary work has been begun at the Government date farms at Indio and Mecca, southern California, in cooperation with the Bureau of Plant Industry, and it is expected that such work will be extended as appears to be advisable.

EVAPORATION STUDY.

In addition to measuring the water resources of the mountains, it is necessary to determine the amount of evaporation in the lower levels, where the storage basins are located. The amount of evaporation in the driest portions of the country, as in the Colorado desert, may amount to as much as 8 feet of water annually, altho it differs greatly according to circumstances. The process of evaporation in nature is very complicated, and especially over a body of water in the open, swept by various winds and subject to great changes of temperature, as between day and night, cloudy and fair weather, winter and summer, the laws are so complex as to have hitherto baffled the researches of many investigators. The importance of securing much more reliable information on this subject has made it desirable to renew the attack upon the problem. The formation of the Salton Sea in the Colorado desert, by the overflow of the Colorado River during the year 1906, affords a favorable laboratory on a large scale at which to make the proposed research on evaporation. A preliminary study on this subject was conducted by Professor Bigelow in the summer of 1907, at Reno, Nev., for the purpose of securing sufficiently adequate knowledge of the phenomena to permit a proper planning of the campaign at the Salton Sea. It was shown that pans evaporate at very different rates over the same body of water, and that the rate of evaporation is dependent on the characteristics of the blanket of invisible vapor that overlies every large body of water.

It is not proper to infer that the evaporation over a lake is the same as that over an isolated pan away from the water. The blanket of vapor tends to conserve the water in the lake, and it may be that the lake evaporates at only five-eighths the rate of an isolated pan. While a pan in the Colorado desert may evaporate at the rate of 8 feet a year, it now seems as if the Salton Sea were avaporating at the rate of only 5 feet a year. The necessary plant will be installed at the Salton Sea during the summer of 1908, and it is hoped that by continuing the observations for two or three years a satisfactory law covering evaporation generally may be secured. The problem is one of unusual difficulty from several points of view, but its practical value is such as to justify a serious effort to solve it. The plan of cooperation with the other Bureaus of the Government has been enlarged to include the Reclamation Service, and the water resources branch of the Geological Survey, which are especially interested in evaporation at the reservoirs, not only of the arid west but in the eastern districts of the country. During the summer of 1908 several plants for the measurement of evaporation will be installed at the reservoirs of the Reclamation Service, and if practicable some other reservoirs in the central and eastern districts will be included. It is important to measure the evaporation in different climates on a uniform plan in order that a comprehensive law may be deduced.

Professor Bigelow, who is in charge of the Records Division, has made some studies on the laws of vortices that are applicable to the explanation of the phenomena of tornadoes, waterspouts, hurricanes or typhoons, and land and ocean-cyclones. It is especially important that the theoretical side of meteorology be developed, because the interpretation of the observations must remain less fruitful until the laws controlling the physical process in the atmosphere are correctly understood.

THE MONTHLY WEATHER REVIEW.

The MONTHLY WEATHER REVIEW has continued to be published regularly within about six weeks of the close of the month to which its data refer. It contains the fundamental climatological averages of the month for all Weather Bureau stations, together with eight charts illustrating the geographical distribution of storms, temperature, sunshine, wind, rain and snow, and river floods. The chapters contributed by the Forecast Division and the Records Division give further details relative to these subjects. The discontinuance of the semiannual chart of the Great Lakes has rendered it appropriate to publish in the MONTHLY WEATHER REVIEW some of the data formerly given on that chart. The remarks furnished by the Forecast Division relative to long-range weather forecasts have been especially appreciated. The opening chapter of the MONTHLY WEATHER REVIEW has always given a general summary of the weather of the current month, but this review now takes a wider range. The introduction of the map showing international weather reports has called attention to the persistent relations between American phenomena and those of Europe and Asia, which relations have justified general forecasts for a week or ten days in advance, the accuracy of which is stimulative to further work along that line; articles on this subject in the MONTHLY WEATHER REVIEW have excited wide attention.

The Chief of Bureau has acknowledged the kind cooperation of numerous meterologists thruout the world who have sent important articles to the columns of the MONTHLY WEATHER REVIEW.

THE TEACHING OF METEOROLOGY.

In pursuance of the policy of the Bureau to aid in eradicating the superstitions everywhere prevailing with regard to the weather, the officials of the Bureau are encouraged in giving popular lectures or explanations, and, when practicable, offering systematic courses of instruction. The minor courses for the benefit of high schools have been numerous and are recorded in detail in the successive numbers of the MONTHLY WEATHER REVIEW. The colleges at which regular courses of instruction were given by Weather Bureau officials, in addition to their regular station duties, were as follows:

Seattle, Wash., University of Washington, G. N. Salisbury.
Syracuse, N. Y., Syracuse University, M. R. Sanford.
Raleigh, N. C., Agricultural and Mechanical College, A. H. Thiessen.
Peoria, Ill., Bradley Polytechnic Institute, D. A. Seeley.
Northfield, Vt., Norwich University, W. A. Shaw.
New Haven, Conn., Yale University, L. M. Tarr.
Madison, Wis., University of Wisconsin, J. L. Bartlett.
Ithaca, N. Y., Cornell University, W. M. Wilson.
Columbia, Mo., University of Missouri, Geo, Reeder.
Columbus, Ohio, Ohio State University, J. Warren Smith.
Cincinnati, Ohio, Cincinnati University, S. S. Bassler.
Canton, N. Y., St. Lawrence University, M. L. Fuller.
Burlington, Vt., University of Vermont, W. H. Alexander.
Berkeley, Cal., University of California, C. Abbe, jr.
Baltimore, Md., Johns Hopkins University, O. L. Fassig.

A method of instruction that is greatly valued consists in the exhibits and local talks at the numerous expositions that have been held during the past twenty years. The work of this nature done at the recent Jamestown Exposition has been highly spoken of. These exposition exhibits involve a heavy expense to the Weather Bureau and much work on the part of its officials, but thousands of citizens are thus reached who would never be able to visit a regular Weather Bureau station.

A novel educational feature has been introduced by the Department of Education of the State of New York, under the general title of "visual education." As a part of this system a popular lecture on meteorology, prepared by Mr. J. R. Weeks,

of Binghamton, N. Y., has been adopted. This lecture, with the accompanying slides, is loaned for repetition before any school or academy.

Translations of special technical articles on the mechanics of the atmosphere, collected for the use of students, have been prepared for publication by the Smithsonian Institution.

The new edition of the Smithsonian Meteorological Tables, as revised by Professors McAdie, Marvin, and Abbe, was published at the beginning of the present fiscal year and copies have been furnished to such Weather Bureau stations as desire them. These tables are widely used by surveyors, meteorologists, and physicists.

The admirable collection by C. F. von Herrmann (now section director) of problems for advanced students of the physics of the atmosphere, published in the MONTHLY WEATHER REVIEW for December, 1906, has been supplemented by a still larger collection that will be published during the coming year. These problems have received many encomiums; they illustrate the character of the instruction in higher meteorology that should be given in our colleges and universities.

The Handbook of Laboratory Experiments leading up to research in meteorology is being amplified by the editor, who expects to complete it during the coming year. It elaborates the idea of a systematic course of instruction for post-graduate students who are working on theses that should bring them the degree of master of science, or doctor of science, or doctor of philosophy, under the regulations that now obtain in all American colleges and universities.

At the present time the tendency of American educational institutions appears to be to assign meteorology to a subordinate position under geography, geology, physics, or other analogous department of learning. This radical error is not committed with regard to astronomy, chemistry, etc., and should be rectified. I wholly agree with the views exprest by my colleague, W. N. Shaw, esq., director of the Meteorological Office, London, in his comments on the life and influence of Alexander Buchan:

> Meteorology, or the physics of the atmosphere, is to be regarded as a separate scientific subject entitled to separate academic recognition. The physics of the atmosphere has its geographical aspect, but it is not a branch of geography; it has its mathematical aspect, but it is not a branch of mathematics; it has its experimental aspect, but it is not a branch of experimental physics.

TELEGRAPH DIVISION.

Extensive general repairs were made to the Port Crescent-Tatoosh Island line during the first part of the fiscal year, and the line is now in excellent order.

On November 6, 1907, the cable between Marthas Vineyard and Nantucket became grounded within 2½ miles of Nantucket. After exhaustive tests it was concluded that it would be impossible to underrun and repair the cable, as it was 23 years old and was heavily sanded all the way. Permission was given to the Western Union cable ship to attempt to do so, without expense to the Government, and in the month of May, 1908, several trials were made by her, but without success. As the Marconi Wireless Company had by this time been handling all the Nantucket telegraph business for a period of more than six months, it was decided to dispose of the defective cable and short land lines at public auction to the highest bidder, which was done on June 30, 1908.

The number of miles of telegraph and telephone lines now operated by the Weather Bureau is 460, inclusive of 110 miles of submarine cables.

The receipts from commercial telegrams handled during the year amounted to $2,781.57.

PUBLICATIONS DIVISION.

As in previous years, the principal work of this division has been the printing and distribution of the Washington Daily Weather Map, MONTHLY WEATHER REVIEW, Weekly and Monthly National Weather Bulletins, and, during the winter months, the Snow and Ice Bulletin. To the above list of regular publications there has been added since last report the Bulletin of the Mount Weather Observatory, a pamphlet containing about 100 pages and issued quarterly. The division has also supplied the observing stations with the requisite blank forms, maps, and forecast cards, and has directed such binding and miscellaneous printing as was authorized for the several divisions of the Bureau. In compliance with executive orders, the mailing lists of all regular publications have been thoroly purged and revised.

OBSERVATORY BUILDINGS.

The observatory buildings reported in my last report as being in course of construction at Anniston, Ala., Birmingham, Ala., Charles City, Iowa, Iola, Kans,, La Crosse, Wis., and Sheridan, Wyo., have been completed and are now in use.

An appropriation of $75,000 has been made for the rebuilding of the main observatory building and for the erection of a central heating and power station at Mount Weather, Va. It is the intention to make these buildings as near fireproof as practicable. As heat and power for all the principal buildings will be supplied from a central station, the danger from fire will be reduced to a minimum.

Buildings owned by the Weather Bureau.

Location.	Cost of ground.	Cost of buildings.	Total cost.
Amarillo, Tex.	$1,255.00	$6,503.00	$7,758.00
Anniston, Ala.	1,799.75	12,920.69	14,720.44
Atlantic City, N. J	(a)	5,991.00	5,991.00
Bentonville, Ark.	500.00	5,119.90	5,619.90
Birmingham, Ala.	(b) 61.50	15,630.36	15,691.86
Bismarck, N. Dak.	(a)	10,085.99	10,085.99
Block Island, R. I.	1,034.50	7,668.25	8,702.75
Burlington, Vt.	(b) 20.00	10,043.50	10,063.50
Cape Henry, Va.	(a)	9,222.45	9,222.45
Charles City, Iowa	3,036.75	9,338.47	12,375.22
Columbia, S. C.	3,799.00	9,165.00	12,964.00
Devils Lake, N. Dak.	2,209.05	7,431.50	9,640.55
Duluth, Minn.	2,041.70	7,430.68	9,472.38
Hatteras, N. C.	(a) (c) 217.00	4,889.75	5,106.75
Havre, Mont.	1,795.00	5,087.08	6,882.08
Iola, Kans.	2,241.25	9,730.94	11,972.19
Jupiter, Fla.	(a)	6,346.90	6,346.90
Key West, Fla.	2,020.00	7,994.75	10,014.75
Kittyhawk, N. C.	(a)	1,616.00	1,616.00
La Crosse, Wis.	3,523.50	12,276.24	15,799.74
Modena, Utah.	(a)	4,346.00	4,346.00
Mount Weather, Va.:			
Administration building (including tower and tank)	1,863.15	20,971.12	22,834.27
Power house and balloon building.	650.00	8,167.00	8,817.00
Absolute building.	(a)	7,000.00	7,000.00
Variation building.	(a)	8,904.55	8,904.55
Stable.	(a)	1,900.00	1,900.00
Barn.	(a)	900.00	900.00
Cottage for workmen.	(a)	1,300.00	1,300.00
Physical laboratory	(a)	27,083.89	27,083.89
Cottage and office	(a)	6,800.00	6,800.00
Mount Washington, N. H.	(c)	300.00	300.00
Nantucket, Mass.	(d)	4,728.53	4,728.53
Narragansett Pier, R. I.	4,151.75	8,036.50	12,188.25
North Head, Wash.	(a)	3,820.13	3,820.13
North Platte, Nebr.	(d)	3,818.50	3,818.50
Oklahoma, Okla.	(b) 38.90	10,520.25	10,559.15
Peoria, Ill.	(b) 54.00	7,875.50	7,929.50
Point Reyes Light, Cal.	(a)	2,875.00	2,875.00
Port Crescent, Wash.	102.00	730.94	832.94
Sand Key, Fla.	(a)	5,593.00	5,593.00
Sault Sainte Marie, Mich.	(a)	2,994.12	2,994.12
Sheridan, Wyo.	2,021.75	12,089.30	14,111.05
Southeast Farallon, Cal.	(a)	5,211.22	5,211.22
Springfield, Ill.	(a)	10,236.50	10,236.50
Tatoosh Island, Wash.	(a)	5,000.00	5,000.00
Washington, D. C.	(d)	174,950.79	174,950.79
Yellowstone Park, Wyo.	(a)	11,156.00	11,156.00
Yuma, Ariz.	(a)	1,500.00	1,500.00
Total	34,435.55	523,301.29	557,763.84

a Government reservation. *b* Donated—figures represent cost of title transfer.
c Leased. *d* Building and ground purchased as a whole. *e* Additional ground purchased.

The building for the central heating and power station has been completed, and an effort will be made to install the boilers and apparatus therein, so that the station may be put into operation by December 15, 1908.

Congress made an appropriation of $15,000 for the completion of the physical laboratory building and the office and

cottage building at Mount Weather, work on these structures having been suspended, as stated in my last report, by reason of a decision by the Comptroller. Work on these buildings was begun promptly on July 1, 1908, and the cottage and office building was completed and occupied September 1, 1908. It is expected that the physical laboratory building will be completed by February 1, 1909.

The appropriation bill for the fiscal year beginning July 1, 1908, also provides for the erection of seven new observatory buildings outside of Washington, D. C. These buildings will be located at Abilene, Tex., Dodge City., Kans., Fort Wayne, Ind., Lansing, Mich., Northfield, Vt., Richmond, Va., and St. Joseph, Mo., and sites have been selected except at Fort Wayne and at Richmond. It is expected that these buildings will be completed and ready for occupancy on July 1, 1909.

The foregoing table shows where the Weather Bureau buildings are located, and gives the cost of the buildings and grounds.

Rented buildings occupied wholly by the Weather Bureau.

Station.	Annual rent.	Other items included.
Alpena, Mich	$650.00	Heat, light, water.
Brawley, Cal	300.00	
Del Rio, Tex	444.00	Heat, light, water.
Durango, Colo	440.00	Do.
East Clallam, Wash	120.00	Water.
Flagstaff, Ariz	300.00	
Helena, Mont	504.00	Steam heating plant, water.
Honolulu, Hawaii	1,020.00	Six rooms; heat, cleaner, light, janitor and porter service, electric current for fan, storage.
Independence, Cal	360.00	Water.
Kalispel, Mont	360.00	
Lewiston, Idaho	540.00	
Manteo, N. C	144.00	
Moorhead, Minn	600.00	Heat, light, water.
Mount Tamalpais, Cal	420.00	Heat, light, water, free transportation of Government employees and supplies.
Pysht, Wash	144.00	Water.
Roseburg, Oreg	550.00	Heat, light, water.
Roswell, N. Mex	720.00	Heat, cleaner, water
San Juan, P. R.	684.00	Four rooms; light, water.
Thomasville, Ga	420.00	
Tonopah, Nev	1,200.00	
Twin, Wash	108.00	Water.
Williston, N. Dak	510.00	Heat, cleaner, light, water.
Winnemucca, Nev	360.00	Heat, light, water.
Total	$10,898.00	

CHANGES IN THE FORCE OF THE BUREAU.

CLASSIFIED SERVICE.

Appointments:
- Probationary—
  - Observer, at $1,200 — 1
  - Printer at $1,200 — 1
  - Printers, at $1,000 — 5
  - Assistant observers, at $720 — 20
  - Repairmen, at $720 — 2
  - Watchman, at $720 — 1
  - Folder and feeder, at $720 — 1
  - Folders and feeders, at $630 — 3
  - Skilled laborers, at $600 — 2
  - Messenger, at $480 — 1
  - Messenger boy, at $480 — 1
  - Messenger boys, at $450 — 4
  - Messenger boys, at $360 — 60

  102
- Transfer—
  - Assistant observer, at $1,000 — 1
- Reinstatement—
  - Assistant observer, at $1,000 — 1
  - Repairman, at $840 — 1
  - Assistant observers, at $720 — 3
  - Messenger boy, at $480 — 1

  6
- Temporary—
  - Compositors, at $1,250 — 3
  - Copyists, at $840 — 4
  - Repairmen, at $720 — 2
  - Watchman, at $720 — 1
  - Skilled laborer, at $660 — 1
  - Folders and feeders, at $630 — 4
  - Messenger, at $480 — 1
  - Messenger boy, at $480 — 1
  - Messenger boys, at $360 — 32

  49
- Emergency—
  - Clerk, at $1,400 — 1
  - Folder and feeder, $630 — 1
  - Skilled laborer, at $600 — 1

  3

Promotions (all promotions were to the next higher grade or by certification for advancement from subclerical positions) — 115

Reductions:
- Causes—
  - Inability to perform satisfactorily work assigned — 3
  - To grant assignment to preferred station — 2
  - To grant assignment to preferred work — 1
  - Neglect of duty — 2
  - Decreased efficiency due to increasing age and ill health — 1
  - Maintaining disrespectful attitude toward official superior — 1
  - As an offset to the Bureau for allowances of quarters, fuel, and light — 1
  - Necessitated by employees' return to duty from leave of absence without pay — 5
  - Because of being permitted to receive compensation regularly from a State — 1
  - To equalize salaries — 1

  18

Resignations:
- Voluntary — 68
- Required because of—
  - Unsatisfactory services — 3
  - Unsatisfactory services and conduct — 2

  73

Transferred to the office of the Secretary of Agriculture — 1

Removals:
- Causes—
  - Misconduct and neglect of duty — 1
  - Absence without authority — 1
  - Absence without authority, and insubordination — 2
  - Defrauding the Government by false vouchers and forgery — 1

  5

Dropped from the rolls at termination of probationary period because of unsatisfactory services — 2

Deaths — 10

UNCLASSIFIED SERVICE.

Appointments:
- Permanent—
  - Unskilled laborers, at $450 — 2
  - Student assistants, at $300 — 2
  - Unclassified laborer, at $240 — 1

  5
- Temporary—
  - Unskilled laborer, at $660 — 1
  - Unskilled laborer, at $450 — 1
  - Student assistant, at $300 — 1
  - Charwoman, at $240 — 1

  4

Promotions (each to next higher grade) — 3

Resignations:
- Voluntary — 1

Removals:
Causes—
Unsatisfactory services 1
Unsatisfactory conduct and services 1
Unsatisfactory conduct and failure to reply to an official communication 1
3

ABSENCE.

Average number of days, with pay, per employee, during calendar year 1907.

	Sickness.	Annual leave.
Station: (99 per cent males)	1.6	6.3
Washington, D. C.:		
Males	5.1	26.4
Females	4.9	28.7
Entire service	2.5	11.4

STATISTICS OF THE SERVICE.

The following tables show the numerical strength of the Bureau and the highest, lowest, and average salaries paid in the commissioned grades:

Numerical strength of the Weather Bureau June 30, 1908.

At Washington, D. C.:		
Classified	179	
Unclassified	11	
		190
Outside of Washington, D. C.:		
Classified	520	
Unclassified	14	
		534
Total commissioned employees		724
Additional employees outside of Washington, D. C.:		
Storm warning display men	181	
River observers	381	
Cotton region observers	143	
Corn and wheat region observers	137	
Rainfall observers	88	
Sugar and rice region observers	9	
Special meteorological observers	9	
Cranberry observers	2	
Total noncommissioned employees		950
Total paid employees		[a] 1,674
Persons serving without compensation (except thru the distribution of Government publications):		
Cooperative observers and correspondents (omitting 87 paid and 4 cooperative river and rainfall observers enumerated elsewhere)	5,734	
Cooperative storm warning display men	74	
Cooperative river observers	16	
Cooperative rainfall observers	10	
Total cooperatives		5,834
Total numerical strength		7,508

Distribution of the commissioned force, June 30, 1908.

In Washington, D. C.:	
Accounts Division	[b] 13
Climatological Division	7
Editor Monthly Weather Review	[c] 3
Executive branch	[d] 18
Forecast Division (including River and Flood Service)	[e] 10
Instrument Division	10
In Washington, D. C.:	
Library	[c] 5
Marine Division	14
Division of Meteorological Records	16
Publications Division	43
Supplies Division	9
Telegraph Division	11
Miscellaneous mechanical work (under direction of the Chief Clerk)	5
Captain of the Watch (under direction of the Chief Clerk)	6
General messenger and laborer service (under direction of Chief Clerk)	18
Total	190
Outside of Washington, D. C.:	
56 stations with 1 commissioned employee	56
57 stations with 2 commissioned employees	114
35 stations with 3 commissioned employees	105
20 stations with 4 commissioned employees	80
10 stations with 5 commissioned employees	50
8 stations with 6 commissioned employees	48
2 stations with 7 commissioned employees	14
3 stations with 8 commissioned employees	24
2 stations with 9 commissioned employees	18
2 stations with 10 commissioned employees	20
1 station with 15 commissioned employees	15
196 stations	[f] 544

[a] This total embraces all paid persons connected with the Bureau on June 30, 1908, except 8 snow and ice reporters who report under certain conditions during the occurrence of snow and ice, and 16 commissioned employees absent on that date and who had been granted leaves of absence or furloughs without pay for one month or more.

[b] One employee devotes a portion of his time at one of the map stations at the United States Capitol.

[c] One employee temporarily assigned.

[d] Two employees temporarily assigned and another devotes a portion of his time at one of the map stations at the United States Capitol.

[e] The River and Flood Service, including two of the commissioned force heretofore assigned as part of the Forecast Division.

[f] This number represents the normal station force. On June 30, 1908, there were actually on regular duty but 534 employees.

In addition to the foregoing there are eight special observing (one-man) stations in the West Indies, mainly in operation during the hurricane season, and a special repair station in Washington, operated from October to April, inclusive.

The following salary table omits persons on duty at special observing and substations where the salaries are $25 a month or less, and where, as a rule, the tour of duty covers but a small fraction of the day and only certain seasons of the year:

Salaries paid in the commissioned grades.

Grades.	June 30, 1908.	
	Station.	Washington, D. C.
CLASSIFIED GRADES.		
Highest salary	$3,000	$5,000
Lowest salary	360	450
Average salary	995	1,189
UNCLASSIFIED GRADES.		
Highest salary	600	720
Lowest salary	240	240
Average salary	343	469

Average salary of all (station and Washington) is $1,022.

GENERAL CLIMATIC CONDITIONS.

By Mr. P. C. DAY, Assistant Chief, Division of Meteorological Records.

PRESSURE.

Compared with the normal the barometric pressure for the year, 1908 was in excess by small amounts over all portions of the United States, except a small area from Michigan westward to the valley of the Red River of the North, and in extreme eastern New England. The area of greatest excess covered the Rocky Mountain region from British Columbia to the Mexican border. Over practically the whole of Canada, except portions of British Columbia, the pressure for the year appears to have been below the normal by small amounts.

TEMPERATURE.

The average temperature for the year 1908 was above the normal in all districts of the United States and Canada, except over the Rocky Mountain and southern portion of the Plateau districts, and along the immediate Pacific coast. Over a vast extent of territory from the great plains eastward to the lower Mississippi and Ohio valleys and from Texas northward into Canada, the mean temperature for the year ranged from 2° to more than 4° above the normal.

The temperature for the various months and seasons of the year 1908 may be summarized as follows:

January was generally warm thruout all portions of the United States until near the end of the month, when a cold wave of considerable severity overspread the more northern districts. While moderate temperatures were the rule over the greater part of the country, some cold weather for the localities occurred along the Gulf coast of Texas and over the Florida Peninsula.

February continued warm over the districts west of the Mississippi, while to the eastward the temperatures were generally below the normal, with frequent and severe periods of cold over the Lake region and New England. Minimum temperatures from 30° to 40° below zero were reported from points in New York and New England, the lowest recorded in those districts in many years, and frosts occurred as far south as the Gulf coast and the central portions of Florida.

March was generally warm thruout, with no unusual extremes of temperature.

The mean temperature for April was above the normal over nearly all districts, and it was one of the warmest Aprils on record over portions of the south Atlantic and east Gulf States. Several moderate cold waves overspread the districts east of the Rocky Mountains, but they were of comparatively short duration.

May was a generally cold month west of the Rocky Mountains and over portions of the Missouri Valley. Over portions of the Plateau districts it was one of the coldest Mays in many years, and frequent and severe frosts occurred over the Pacific coast States. A rather severe cold wave occurred during the first few days of the month over the districts east of the Rocky Mountains, and frosts occurred over portions of the lower Mississippi Valley at a later date than for many years,

In June the average temperature was below the normal over nearly all the districts west of the Mississippi River, and it was an unusually cool month over portions of the central and northern Plateau districts, where frequent and damaging frosts occurred. East of the Mississippi River the temperatures were nearly normal, except about the first of the month, and again on the 15th, when unusually cold weather occurred in the Lake region and portions of northern New England.

July was without decided variations from the normal, except over portions of the north Pacific coast and northern Plateau where the month was unusually warm.

During August, warm weather continued over portions of the north Pacific coast, but the temperature was generally below the normal in other portions of the United States west of the Mississippi River. Over the districts east of the Mississippi no unusual variations from the normal occurred.

September was marked by uniformly high temperatures over the greater part of the United States, especially from New England westward over the Lake region, Ohio, Mississippi, and Missouri valleys to the Rocky Mountains, where the mean temperature for the month ranged from 3° to 7° per day above the normal. The temperature during the latter part of the month was unseasonably warm in the Lake region, and the Ohio and upper Mississippi valleys, the daily means ranging from 10° to 15° above the normal. During the latter part of the month cool weather set in over the Pacific coast, and by the end of the month had extended well into the Missouri and Mississippi valleys, bringing unusually cold weather for September over large portions of the districts from the north Pacific coast southeastward over the Plateau, Rocky Mountain, and Great Plains districts to central Texas.

The beginning of October was marked by generally cold weather over the central and eastern districts, due to the presence of an extensive area of high pressure over the upper Mississippi Valley, and cool weather continued over those districts until near the middle of the second decade when warm weather set in over the districts east of the Rocky Mountains, and continued without material interruption to near the end of the month. Over the districts west of the Rocky Mountains the weather was generally cool, and some unusually low minimum temperatures occurred along the Pacific coast and in southern Arizona. The month closed with cold weather prevailing over practically all districts except the northern Rocky Mountain and Plateau districts.

The cold weather prevailing at the end of October continued over the more eastern districts to about the 5th of November, during which time some unusually low temperatures occurred over the Ohio Valley, Middle Atlantic States, and New England. From the 5th to the 10th warm weather prevailed generally over all interior districts, but about the latter date an area of decided cold advanced from the northwest and by the 16th had overspread practically all districts east of the Rocky Mountains, the minimum temperature of the 13th going below zero in portions of the central Rocky Mountain region, and freezing temperatures occurred over all districts in the United States, except the immediate south Atlantic and Gulf coasts and over the lower elevations of the Pacific coast States. After the 16th generally warm weather prevailed to the end of the month, except in the upper Missouri Valley where, on the 30th, a decided cold wave was being experienced.

The cold wave over the upper Missouri Valley on November 30 gradually overspread the districts eastward and southward by December 4, and was followed by another during the 6th to 8th, after which moderate temperatures prevailed until about the 30th, when another cold wave appeared and by the end of the year had overspread the districts from the Rocky Mountains to the Mississippi and Ohio valleys and Lake region.

PRECIPITATION.

The annual precipitation for 1908 was less than the usual amount over all districts east of the Mississippi, except along the eastern slopes of the Appalachian Mountains from northern Virginia to western South Carolina, over the greater portions of the lower elevations of Virginia and North Carolina, and along the eastern and southern coasts of Florida. Precipita-

tion was also below the normal over the greater portions of Arkansas, Louisiana, and Texas, in the southern Rocky Mountain region, and generally over the Plateau and Pacific coast States. From the Mississippi River westward to the Rocky Mountain districts, except in the portions of Arkansas, Louisiana, Texas, and the southern Rocky Mountain region mentioned above, the precipitation for the year was above the normal. At points in southern Kansas, central Oklahoma, and northern Texas the excess ranged from 10 to 20 inches.

The most pronounced feature of the weather of the year 1908 was the remarkably severe and long-continued drought during the late summer and early fall months over the greater part of the Ohio Valley and Lake region, portions of the Middle Atlantic States and New England. The combined effect of high temperature and deficient rainfall during the latter part of August and thruout the most of September, October, and November resulted in one of the most disastrous droughts in the meteorological history of those districts.

The occurrence of this drought rather late in the season of crop growth and development did not result in such widespread disaster to agricultural interests as might have resulted had it occurred slightly earlier, but serious inconvenience resulted from the failure of the water supply. Many manufacturing establishments were forced to shut down or seriously curtail their production. The drying up of the streams and springs greatly inconvenienced the farmers in procuring water for their cattle and domestic supplies, the supply to cities and towns was greatly reduced, and the dry conditions of the forests made possible the occurrence, in portions of the Lake region and New England, of the most disastrous forest fires on record.

Rather full details of the above-mentioned drought will be found in the MONTHLY WEATHER REVIEW for the several months, and in the Monthly Climatological Summaries of the States located in the region affected.

Minor periods of drought occurred in Florida during February and March, and in New England during the latter part of June and early part of July.

Heavy rains in portions of Washington, Oregon, and Idaho during March 13 to 15 caused disastrous floods in the streams of those States and much damage was done. Heavy rains in the watershed of the Ohio during March also caused floods in that river and some of its tributaries, but without material damage.

During April high waters again prevailed in the Ohio and its southern tributaries, due to heavy rains in West Virginia and Kentucky during the latter part of March and the first of April.

Heavy rains in the Mississippi Valley, together with the flood from the Ohio River caused the Mississippi River to pass the flood stage during most of the month from Cairo to the Gulf. No material damage occurred, however. High waters also prevailed in the rivers of northern and eastern Texas.

During May heavy rains in north central Texas and the surrounding territory, from the 21st to 24th inclusive, resulted in the most disastrous floods known in portions of Texas and Oklahoma. A number of persons were drowned and millions of dollars worth of property destroyed.

During June heavy rainfall in the districts between the Mississippi River and the Rocky Mountains resulted in floods in many of the streams and rivers of that territory, and several million dollars' worth of property was destroyed. Full accounts of these floods appear in the REVIEW for June and July.

During the latter part of August heavy rains in the southern Appalachian mountain districts caused disastrous floods in the rivers from southern Virginia to Georgia. Some of the streams rose to greater heights than ever known before and much damage was done.

Heavy rains in eastern Colorado and over the greater part of Kansas and Oklahoma from October 18 to 22 caused high waters and extensive floods in those States, with property losses amounting to several millions of dollars.

During the last few days of November heavy rains again occurred over portions of Oklahoma and Kansas, causing floods of considerable proportions in the streams of those States during the latter part of November and the first part of December.

SNOWFALL.

Snowfall during January was light in the upper Lake region and there was a general deficiency in the mountain regions of the West.

During February generally heavy snows occurred over all northern districts from the northern Rocky Mountains to New England, but the amounts were generally light in other districts.

March snowfall was rather heavy from the upper Lakes westward to the Rocky Mountains and light in the remaining portions of the country.

During April the snowfall was generally light, except over portions of the upper Lake region and also in portions of central and eastern Ohio and in the mountains of West Virginia and western Pennsylvania, where on April 30 snow from 2 to 15 inches in depth occurred, a very unusual fall for so late in the season.

In May some heavy falls of snow occurred over the eastern slopes of the Rocky Mountains from Colorado to Montana, and heavy falls also occurred locally in the mountains of California and portions of the Plateau region.

In October heavy snows occurred in the mountains of the West, especially along the Main Divide, causing the loss of several human lives and much suffering and loss of life to cattle and sheep caught in the high ranges without protection.

Heavy snows for the season occurred over the Appalachian Mountain districts on November 13 and 14, and during the latter part of the month some unusually heavy falls occurred over the western slopes of the Rocky Mountains from Wyoming to New Mexico, and over the Great Plains from Kansas to North Dakota. Over other portions of the United States the snowfall during November was light.

December was a month of generally well-distributed snowfall with local heavy falls in portions of the Middle Atlantic States, northern New York, the lower Michigan Peninsula and on the western slopes of the mountains of Wyoming, Colorado and northern Arizona, and in portions of Utah.

SEVERE WIND STORMS.

Severe winds visited Illinois on March 27 and May 5.

Severe tornadoes occurred at numerous points in Louisiana and Mississippi on April 23 and 24, resulting in the loss of many lives and much damage to property. Similar storms, but of less violence, occurred in portions of Texas, Louisiana, Missouri, and Nebraska on May 12 and 13, in Minnesota on May 24, and in Wyoming on May 31.

During June severe storms possessing the characteristics of tornadoes were reported from many points in Nebraska, South Dakota, and Wisconsin. Severe windstorms also swept across Ohio on June 19.

Ohio was again visited by a tornado on August 12 and by a destructive thundersquall on August 17.

November brought tornadoes to New Mexico and Oklahoma on the 5th, to Arkansas and Oklahoma on the 23d, and to Arkansas and Wisconsin on the 25th. The Arkansas tornadoes of the 23d were numerous and very destructive.

TABLE I.—*Annual climatological summary, Weather Bureau stations, 1908.*

Districts and stations.	Elevation of barometer above sea level.	Pressure in inches.*			Temperature of the air, in degrees Fahrenheit.							Mean temperature of the dew-point.	Mean relative humidity, per cent.	Precipitation.			Winds.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall, inches. †
		Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Mean maximum.	Minimum.	Mean minimum.	Annual range.			Total, in inches.	Departure from normal.	Days with .01, or more.	Total movement, miles.	Prevailing direction.	Max. velocity: Miles, per hour.	Max. velocity: Direction.					
New England.					**65.9**	**+1.3**							**74**	**34.00**	**— 7.91**								**5.3**	
Eastport	76	29.88	29.96	—.01	42.5	+1.4	86	50	—11	35	97	35	77	35.56	— 7.86	137	99,668	s.	69	se.	69	145	152	6.5	91.7
Portland, Me	103	29.88	30.00	.00	46.0	+0.6	98	54	— 5	38	103	36	70	30.74	—11.90	120	85,037	sw.	61	se.	148	106	112	5.0	49.8
Concord	288	29.70	30.01	—.01	46.3	+0.7	95	57	—11	36	106	.....	.....	26.25	—13.95	110	49,455	nw.	40	nw.	228	67	71	3.5	56.6
Burlington	404	29.57	30.02	+.01	44.2	+1.2	96	54	—27	35	123	.....	.....	23.49	— 8.12	144	106,195	s.	70	s.	95	115	156	6.2	71.8
Boston	125	29.88	30.02	+.01	51.1	+1.3	97	59	— 2	43	99	40	70	30.07	—13.43	107	96,500	sw.	48	sw.	129	108	129	5.5	26.2
Nantucket	12	30.00	30.01	—.01	50.0	+0.4	89	56	3	44	86	44	84	35.78	— 1.33	124	144,656	sw.	83	ne.	124	128	114	5.7	22.7
Block Island	26	30.00	30.03	+.01	50.1	+0.5	87	56	4	44	83	43	78	36.47	— 8.02	112	155,702	sw.	74	n.	136	127	103	5.0	15.4
Providence	160	29.86	30.04	+.02	50.3	+0.5	95	60	— 2	41	97	39	71	36.09	— 7.41	120	64,236	w.	37	e.	160	114	92	4.7	34.1
Hartford	159	29.86	30.04	+.02	50.5	+2.0	96	60	— 6	41	102	40	72	42.36	— 3.07	115	66,421	s.	48	s.	101	135	130	5.9	40.6
New Haven	106	29.92	30.04	+.01	51.3	+1.8	94	60	— 3	43	97	40	70	43.33	— 3.98	117	81,670	n.	54	se.	151	121	94	4.7	44.0
Middle Atlantic States.					**53.6**	**+1.0**							**74**	**38.59**	**— 2.93**								**5.4**	
Albany	97	29.93	30.03	.00	49.1	+1.5	93	58	—15	40	108	39	71	28.41	— 8.05	118	64,644	s.	41	nw.	110	153	103	5.4	49.0
Binghamton	871	29.10	30.04	.00	47.4	+0.8	95	58	—21	37	116	.....	.....	27.16	— 5.87	134	56,184	w.	39	w.	78	97	191	6.6	70.3
New York	314	29.70	30.04	.00	53.5	+1.8	93	60	1	46	92	43	70	41.43	— 3.33	104	107,095	nw.	60	w.	128	126	112	5.1	32.2
Harrisburg	374	29.66	30.07	+.02	52.9	+1.3	97	61	1	44	96	41	69	33.47	— 3.91	108	63,573	w.	46	nw.	140	118	108	5.0	44.2
Philadelphia	117	29.97	30.07	+.02	55.5	+1.9	97	63	5	48	92	45	72	38.13	— 3.14	109	87,987	nw.	42	se.	131	124	111	5.1	25.8
Scranton	805	29.18	30.03	+.01	50.1	+1.4	95	60	— 7	40	102	39	69	32.59	— 4.56	126	63,733	sw.	44	w.	100	109	157	6.0	66.7
Atlantic City	52	30.01	30.07	+.03	53.1	+0.7	92	60	6	46	86	45	76	37.88	— 3.05	112	74,537	sw.	43	se.	112	110	144	5.7	12.8
Baltimore	123	29.93	30.06	+.01	56.2	+1.1	98	64	9	48	89	45	70	35.41	— 7.89	109	62,465	sw.	40	ne.	116	98	152	5.7	17.3
Washington	112	29.94	30.07	+.01	55.4	+0.7	99	65	6	46	93	44	71	38.33	— 5.28	112	61,455	nw.	43	nw.	134	126	106	5.1	18.3
Lynchburg	681	29.34	30.09	+.02	56.8	+0.4	97	67	12	47	85	47	76	42.71	— 0.84	107	34,080	nw.	27	nw.	141	123	102	5.2	18.2
Mount Weather	.....	28.22	30.05	—.01	50.8	+1.2	89	58	4	43	85	42	76	39.55	— 2.12	123	123,849	nw	75	nw.	124	117	125	5.4	30.9
Norfolk	91	29.98	30.08	+.03	60.1	+1.0	94	68	19	52	75	51	76	44.25	— 5.41	124	82,825	s.	56	se.	142	104	120	5.0	8.8
Richmond	144	29.93	30.08	+.02	58.4	—0.1	96	68	15	49	81	.....	.....	52.78	+11.04	123	70,030	s.	52	sw.	155	101	110	4.8	13.8
Wytheville	2,293	27.70	30.09	+.02	52.4	—0.2	90	63	3	42	87	46	86	48.20	+ 1.35	149	44,831	w.	40	nw.	154	104	108	4.8	30.7
South Atlantic States.					**63.5**	**+1.1**							**77**	**48.32**	**— 1.69**								**5.1**	
Asheville	2,255	27.73	30.09	+.02	55.5	+1.4	90	66	5	45	85	47	81	46.35	— 3.36	115	64,901	se.	44	e.	127	129	110	5.1	23.9
Charlotte	773	29.25	30.09	+.02	60.4	+0.5	95	69	17	51	78	48	71	54.40	+ 5.08	113	58,751	ne.	40	sw.	132	124	110	5.2	5.6
Raleigh	376	29.67	30.08	+.02	60.4	+0.8	96	70	16	51	80	49	72	56.63	+ 6.90	115	61,519	ne.	40	sw.	143	116	107	5.0	5.0
Wilmington	78	29.99	30.08	+.02	63.7	+1.5	93	72	21	55	72	54	79	53.98	+ 2.84	117	73,341	ne.	48	ne.	134	156	76	4.7	0.4
Charleston	48	30.02	30.07	.00	66.7	+1.1	95	74	26	60	69	58	81	31.41	—20.76	102	97,059	sw.	47	ne.	131	161	102	4.6	
Columbia, S. C	351	29.69	30.07	.00	63.8	+0.6	97	74	29	54	77	51	72	44.48	— 1.72	111	62,538	ne.	44	sw.	108	149	109	5.4	0.4
Augusta	180	29.88	30.07	.00	64.7	+1.1	96	75	21	55	75	54	76	44.62	— 3.39	108	55,960	ne.	57	sw.	177	113	76	4.1	T.
Savannah	65	30.00	30.07	+.01	67.2	+1.7	97	76	25	59	72	57	78	47.56	— 2.90	113	66,316	w.	36	w.	135	127	104	5.0	
Jacksonville	43	30.02	30.07	+.01	69.3	+1.1	95	77	28	62	67	62	84	55.44	+ 2.09	112	81,647	ne.	68	s.	144	138	84	4.8	
Florida Peninsula.					**74.4**	**+0.7**							**80**	**47.17**	**— 3.60**								**4.4**	
Jupiter	28	30.01	30.04	+.01	74.9	+0.2	95	80	40	67	55	67	82	70.42	+10.05	161	92,647	se.	48	nw.	83	224	59	5.2	
Key West	22	30.01	30.03	—.02	76.8	0.0	91	82	51	72	40	68	78	38.83	+ 0.12	108	77,885	ne.	50	w.	166	153	47	4.2	
Tampa	35	30.03	30.06	+.02	72.3	+1.9	96	81	33	64	63	63	79	32.25	—20.96	109	67,337	ne.	40	w.	184	127	55	3.8	
East Gulf States.					**65.9**	**+1.3**							**75**	**47.12**	**— 5.70**								**5.1**	
Atlanta	1,174	28.84	30.08	+.01	61.7	+0.8	96	70	16	53	80	50	73	48.83	— 0.66	109	99,649	nw.	56	nw.	160	92	114	5.0	2.5
Macon	370	29.68	30.08	+.02	65.0	+2.1	97	75	22	55	75	.....	.....	50.11	+ 2.98	105	47,099	nw.	31	w.	146	113	107	4.8	T.
Thomasville	273	29.78	30.08	+.02	67.6	+0.5	97	79	23	56	74	58	80	40.90	— 9.71	112	47,160	s.	38	sw.	164	118	84	4.4	
Pensacola	56	30.01	30.07	+.02	68.3	+0.4	93	75	28	61	65	.....	.....	42.01	—14.40	102	84,799	ne.	44	se.	135	117	114	5.0	
Anniston	741	29.31	30.10	+.04	62.6	+1.9	98	73	16	52	82	.....	.....	43.80	— 5.69	108	52,308	se.	40	se.	116	84	166	6.0	T.
Birmingham	700	29.32	30.09	+.03	64.1	+0.5	98	74	17	55	81	52	72	39.52	—10.11	103	60,559	e.	43	se.	84	158	124	5.8	T.
Mobile	57	30.00	30.06	+.01	68.4	+2.3	97	76	28	60	69	58	78	56.90	— 5.30	107	63,190	se.	36	se.	137	164	65	4.7	
Montgomery	223	29.83	30.08	+.02	66.0	+0.9	98	76	22	56	76	53	70	46.06	— 5.28	98	57,221	e.	48	s.	119	132	115	5.4	
Meridian	375	29.67	30.06	.00	64.6	+1.5	95	75	20	54	75	54	75	49.89	— 3.45	101	47,899	sw.	34	w.	163	100	103	4.8	T.
Vicksburg	247	29.79	30.07	+.01	66.4	+1.6	96	75	24	58	72	55	74	49.22	— 4.66	112	58,655	se.	46	nw.	141	119	106	4.8	
New Orleans	51	30.00	30.05	+.01	70.1	+1.1	94	78	32	62	62	60	78	51.06	— 6.46	114	74,229	se.	40	se.	109	167	90	5.1	
West Gulf States.					**68.3**	**+1.4**							**74**	**39.71**	**— 0.11**								**4.6**	
Shreveport	249	29.78	30.05	+.02	66.6	+1.4	97	76	23	57	74	55	73	58.06	+ 1.40	108	61,861	se.	52	se.	150	116	100	4.8	
Bentonville	11	28.65	30.02	—.01	58.3	+1.3	95	69	7	48	88	.....	.....	46.56	+ 3.44	107	53,093	s.	32	sw.	168	105	93	4.6	24.1
Fort Smith	457	29.54	30.02	—.01	62.1	+1.6	94	72	14	52	83	51	72	52.68	+11.26	107	70,944	e.	48	w.	154	122	90	4.6	T.
Little Rock	357	29.67	30.05	+.01	63.3	+1.8	96	72	18	54	78	51	70	37.05	—13.00	107	78,310	s.	59	s.	145	125	96	4.7	T.
Corpus Christi	20	29.99	30.01	+.02	71.9	+1.9	95	78	35	66	60	63	79	19.00	— 8.24	74	98,117	se.	47	e.	143	138	85	4.6	
Fort Worth	670	29.31	30.02	+.01	65.9	+0.9	100	76	20	56	80	.....	.....	45.07	+18.13	89	91,684	s.	53	nw.	163	144	59	4.2	T.
Galveston	54	29.99	30.05	+.02	70.3	+0.9	91	75	32	66	59	63	82	42.01	— 5.16	89	100,344	se.	62	ne.	152	142	72	4.6	
Palestine	510	29.49	30.02	.00	66.8	+1.6	96	76	23	58	63	56	75	33.85	— 9.29	100	53,587	s.	42	w.	76	126	139	5.8	T.
San Antonio	701	29.27	30.00	+.01	69.7	+1.8	102	80	22	59	80	56	70	28.32	+ 1.60	81	60,263	se.	47	nw.	149	143	74	4.6	
Taylor	583	29.41	30.02	+.02	67.8	+1.3	100	78	39	58	80	.....	.....	34.32	— 1.25	88	78,485	s.	48	nw.	177	106	83	4.1	0.3
Ohio Valley and Tenn.					**57.0**	**+1.4**							**70**	**36.01**	**— 7.53**								**5.3**	
Chattanooga	762	29.28	30.10	+.03	61.2	+1.3	95	71	13	52	82	49	71	42.17	— 8.67	127	52,983	sw.	42	nw.	114	120	132	5.6	0.7
Knoxville	1,004	29.02	30.08	+.01	59.1	+1.7	95	69	12	50	83	48	72	38.38	—11.15	119	42,587	ne.	34	sw.	92	112	162	6.1	1.0
Memphis	399	29.65	30.08	+.03	63.0	+1.7	95	71	16	55	79	53	74	47.46	— 3.02	103	74,863	s.	61	w.	146	83	137	5.2	0.1
Nashville	546	29.50	30.08	+.02	60.8	+1.5	97	70	14	51	83	49	71	34.04	—14.59	113	51,858	sw.	42	se.	121	105	140	5.5	T.
Lexington	989	29.00	30.08	+.02	56.1	+1.1	94	65	5	47	89	.....	.....	37.60	— 4.59	121	99,041	s.	49	sw.	166	78	122	4.8	15.7
Louisville	525	29.49	30.07	+.01	58.7	+1.9	98	68	7	49	91	45	66	37.85	— 6.57	115	70,135	sw.	48	w.	136	120	110	5.0	7.5
Evansville	431	29.58	30.05	.00	58.3	+1.9	97	67	8	50	89	.....	.....	35.69	— 7.56	108	65,716	s.	43	sw.	113	188	65	4.8	12.4
Indianapolis	822	29.16	30.05	+.01	54.1	+1.4	95	63	0	45	95	42	68	31.25	—10.35	110	88,388	sw.	48	sw.	110	123	133	5.8	15.6
Cincinnati	628	29.38	30.06	.00	56.6	+1.4	98	66	3	47	95	42	63	27.29	—11.13	113	89,336	•w.	40	w.	136	117	113	5.1	9.7
Columbus	824	29.18	30.06	+.01	53.5	+1.4	96	63	1	44	95	41	68	30.14	— 6.86	121	102,886	se.	70	w.	140	124	102	4.8	13.8
Pittsburg	842	29.14	30.06	+.01	53.2	+0.5	94	62	— 1	44	95	41	68	30.17	— 6.27	135	86,088	nw.	67	w.	110	138	118	5.4	27.9
Parkersburg	638	29.41	30.07	+.01	55.1	—1.5	98	65	7	45	91	44	74	31.83	— 8.50	129	50,539	s.	48	nw.	142	108	116	5.4	7.2
Elkins	1,940	28.02	30.10	+.04	51.2	+1.3	92	63	— 8	39	100	42	80	44.25	+ 1.38	167	33,874	w.	34	ne.	135	96	135	5.6	48.9
Lower Lake Region.					**48.6**	**+0.8**							**73**	**30.15**	**— 4.79**								**5.6**	
Buffalo	767	29.18	30.02	.00	47.9	+0.9	88	55	— 8	41	96	40	76	34.24	— 3.12	169	131,789	sw.	76	sw.	104	134	128	5.7	70.3
Canton	.....	29.52	30.01	—.01	43.1	—0.9	92	53	—40	33	132	.....	.....	33.60	— 2.66	168	104,589	sw.	65	w.	125	106	135	5.6	83.4
Oswego	335	29.64	30.01	—.01	46.8	0.0	91	55	—18	39	109	39	77	33.93	— 2.33	157	97,782	s.	44	w	107	95	164	6.0	81.7
Rochester	523	29.45	30.03	+.01	48.7	+1.7	92	57	— 5	40	97	38	71	27.49	— 6.86	150	79,623	sw.	46	w.	108	103	155	6.0	67.3
Syracuse	597	29.38	30.03	.00	47.8	+0.6	92	56	—17	39	109	.....	.....	26.96	— 7.42	160	106,923	s.	62	s.	93	105	168	6.3	74.6
Erie	713	29.25	30.03	.00	49.7	+0.9	90	57	— 4	42	94	39	68	26.72	—11.91	139	100,171	s.	54	w.	128	97	141	5.5	45.7
Cleveland	762	29.21	30.03	—.01	50.4	+1.1	92	58	0	43	92	40	69	27.60	— 7.52	153	132,166	se.	60	w.	121	115	130	5.4	69.5
Sandusky	629	29.35	30.03	—.01	51.1	+1.1	95	59	4	44	91	.....	.....	26.48	— 7.61	121	75,868	sw.	40	nw.	148	93	125	4.8	31.7
Toledo	628	29.35	30.04	+.01	50.9	+1.3	97	59	1	42	96	40	71	35.88	+ 5.21	120	128,750	sw.	60	sw.	167	96	103	4.6	37.0
Detroit	730	29.24	30.04	+.01	49.3	+1.1	95	58	— 2	41	97	41	77	28.59	— 3.65	120	125,729	sw.	58	sw.	120	100	146	5.7	67.2
Upper Lake Region.					**45.1**	**+1.9**							**76**	**28.38**	**— 3.52**								**5.9**	
Alpena	609	29.33	30.00	+.01	43.5	+1.8	94	52	—13	34	107	36	79	25.61	— 7.66	135	97,872	nw.	52	se.	93	122	151	6.1	71.8
Escanaba	612	29.32	30.00	—.01	42.5	+1.9	90	50	—12	35	102	35	77	23.93	— 7.63	119	90,168	s.	56	e.	83	113	170	6.3	71.2
Grand Haven	632	29.32	30.00	—.02	47.4	+0.7	90	55	0	40	90	40	76	33.35	+ 1.90	126	112,183	sw.	51	nw.	114	128	124	5.6	58.8
Grand Rapids	707	29.24	30.02	.00	49.0	+0.9	95	58	— 1	40	96	39	73	31.17	— 0.37	119	101,148	sw.	48	sw.	83	121	162	6.4	43.4
Houghton	668	29.23	29.97	—.03	42.4	+2.2	92	51	—19	34	111	.....	.....	29.85	— 2.84	170	66,099	e.	36	nw.	78	130	158	6.4	88.6
Marquette	734	29.18	29.99	—.01	43.1	+2.6	94	51	— 9	36	103	33	71	30.29	— 2.42	158	97,572	nw.	48	sw.	66	150	150	6.2	131.9
Port Huron	638	29.32	30.02	.00	47.1	+1.8	95	56	— 9	38	104	39	75	24.29	— 6.53	114	102,802	sw.	69	w.	128	101	137	5.6	55.1
Sault Sainte Marie	614	29.30	30.00	.00	40.8	+2.4	92	40	—25	32	117	34	80	26.06	— 5.37	150	80,593	se.	48	w.	80	85	201	6.9	57.9
Chicago	823	29.14	30.03	.00	51.7	+3.2	96	59	— 2	45	98	43	75	34.83	+ 1.47	109	132,751	sw.	68	w.	133	116	117	5.1	68.9

TABLE I.—*Annual climatological summary, Weather Bureau stations, 1908*—Continued.

Districts and stations.	Elevation of barometer above sea level.	Pressure in inches.*			Temperature of the air, in degrees Fahrenheit.							Mean relative humidity, per cent.	Precipitation.			Winds.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall, inches.†
		Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Mean maximum.	Minimum.	Mean minimum.	Annual range.	Mean temperature of the dew-point.	Total, in inches.	Departure from normal.	Days with .01, or more.	Total movement, miles.	Prevailing direction.	Max. velocity. Miles, per hour.	Max. velocity. Direction.					
Upper Lake Region—Con.																								
Milwaukee	681	29.28	30.03	+.01	47.8	+2.5	95	55	−7	40	102	39	76	28.32	−3.16	102	96,611	w.	50	se.	165	115	86	4.4	67.6
Green Bay	617	29.31	29.98	−.03	45.7	+2.7	95	55	−15	37	110	36	73	21.92	−9.28	106	97,631	sw.	59	w.	89	118	159	6.4	53.6
Duluth	1,133	28.74	29.98	−.03	39.8	−0.4	92	48	−29	31	121	32	79	31.05	+1.08	104	119,437	ne.	60	w.	105	148	113	5.5	43.4
North Dakota.					42.2	+3.0							75	21.42	+0.12									5.1	
Moorhead	940	28.97	30.00	−.01	41.6	+3.2	96	52	−29	31	125	34	81	25.93	+0.98	103	78,468	nw.	40	nw.	145	102	119	4.9	46.1
Bismarck	1,674	28.21	30.02	+.02	42.7	+2.7	100	55	−21	31	121	31	69	16.91	−0.75	85	101,619	nw.	68	nw.	119	142	105	5.3	34.2
Upper Miss. Valley.					51.5	+1.8							72	32.12	−2.83									5.0	
St. Paul	837	29.08	29.99	−.02	46.0	+2.1	96	55	−24	37	120	35	69	31.60	+2.89	105	96,377	nw.	54	sw.	133	149	84	4.9	39.7
La Crosse	714	29.22	30.00	−.02	47.6	+1.7	95	57	−13	38	108	.....	.....	31.57	+0.35	106	51,154	s.	28	sw.	99	106	161	5.9	29.1
Madison	974	28.95	30.01	−.01	47.1	+1.7	94	56	−10	38	104	38	73	25.67	−6.12	102	91,202	sw.	54	ne.	137	114	115	5.1	28.8
Charles City	1,015	28.93	30.02	.00	46.7	+2.1	94	57	−14	36	108	39	80	34.19	+2.92	95	77,995	nw.	35	ne.	83	144	139	6.0	28.7
Davenport	606	29.36	30.02	−.01	51.2	+1.8	95	60	−4	42	99	42	72	31.50	−1.14	101	70,128	nw.	39	s.	157	96	113	4.8	24.3
Des Moines	861	29.09	30.01	−.01	50.9	+1.6	95	61	−7	41	102	41	72	35.89	+3.40	101	76,865	sw.	40	sw.	105	157	104	5.5	23.7
Dubuque	698	29.28	30.04	+.02	49.2	+1.3	96	58	−8	40	104	39	72	24.11	−9.96	99	56,636	se.	42	n.	144	106	116	5.1	27.5
Keokuk	614	29.36	30.04	+.01	53.8	+2.4	95	63	−2	44	97	42	72	34.28	−0.85	91	67,328	nw.	39	sw.	188	105	73	3.9	22.1
Cairo	356	29.68	30.06	+.01	59.6	+2.0	96	68	10	51	86	48	70	38.47	−3.35	121	77,916	s.	48	s.	127	109	130	5.4	13.2
Peoria	609	29.37	30.05	+.02	51.6	+1.7	95	62	−3	41	98	41	73	33.96	−2.42	107	76,437	s.	49	sw.	182	103	81	4.2	18.2
Springfield, Ill.	644	29.34	30.03	+.01	54.2	+2.0	97	64	2	45	95	42	68	29.68	−7.38	99	79,649	s.	44	w.	168	91	107	4.6	31.7
Hannibal	534	29.45	30.03	.00	54.2	+1.1	95	64	−1	44	96	.....	.....	32.35	−1.98	114	83,735	sw.	50	sw.	153	84	129	5.0	25.6
St. Louis	567	29.42	30.03	−.01	57.4	+1.6	98	66	6	49	92	45	68	34.19	−3.12	102	89,016	s.	46	sw.	156	84	126	5.1	19.7
Missouri Valley.					52.0	+2.5							69	32.90	+3.86									4.8	
Columbia, Mo.	784	29.82	30.03	.00	55.2	+1.7	97	66	2	45	95	.....	.....	40.57	+3.87	108	72,484	s.	52	sw.	142	117	107	4.8	28.4
Kansas City	963	28.98	30.02	−.02	55.9	+2.7	94	65	4	47	80	44	68	39.48	+2.04	97	114,427	s.	57	n.	156	137	73	4.4	8.3
Springfield, Mo.	1,324	28.63	30.03	.00	56.7	+1.9	93	66	4	47	89	46	74	43.32	−1.36	118	91,934	se.	48	nw.	209	84	73	3.6	24.6
Iola, Kans.	.....	28.98	30.03	+.01	57.1	+3.0	97	68	5	46	92	.....	.....	45.30	+12.92	100	68,642	s.	39	ne.	106	143	117	5.6	7.3
Topeka	.....	.....	.....	.....	55.6	+2.3	94	66	3	45	91	.....	.....	43.20	+9.38	96	83,695	s.	51	nw.	177	127	62	4.0	5.0
Lincoln	1,189	28.73	30.01	.00	52.4	+2.3	98	63	−4	42	102	40	68	35.69	+8.14	99	96,728	s.	63	sw.	148	126	92	4.8	21.6
Omaha	1,105	28.83	30.02	.00	52.3	+2.3	96	61	−3	43	99	40	69	27.10	−3.59	90	81,703	nw.	44	n.	123	101	142	5.5	21.2
Valentine	2,598	27.28	30.02	+.02	47.7	+1.4	101	61	−13	35	114	34	67	19.51	+3.55	92	98,641	nw.	52	nw.	154	167	45	4.2	24.9
Sioux City	1,135	28.79	30.01	−.01	49.1	+2.0	96	59	−10	39	106	.....	.....	26.44	+0.45	86	115,673	nw.	60	ne.	137	109	120	5.0	17.2
Pierre	1,572	28.33	30.01	−.01	48.6	+3.0	102	60	−13	37	115	33	61	19.10	+2.44	72	92,010	nw.	55	nw.	135	141	90	4.8	22.6
Huron	1,306	28.60	30.02	+.01	45.4	+3.3	99	57	−15	34	114	35	73	28.67	+7.54	91	89,921	se.	47	nw.	154	103	109	4.8	31.1
Yankton	1,233	28.67	30.00	.01	48.6	+2.0	100	60	−14	38	114	.....	.....	26.39	+0.93	84	76,329	nw.	43	nw.	117	95	154	5.8	18.5
Northern Slope.					43.7	0.0							66	18.28	+1.88									4.9	
Havre	2,505	27.32	29.98	+.01	44.0	−2.1	106	57	−19	31	125	33	72	11.92	−1.77	80	83,170	nw.	52	sw.	175	140	51	4.3	28.3
Helena	4,110	25.81	30.04	+.03	44.0	+0.8	98	54	−14	34	112	30	63	19.63	+6.84	88	61,686	sw.	49	w.	119	113	134	5.5	27.5
Kalispell	2,962	26.93	30.02	+.03	43.5	+1.1	92	54	−14	33	106	32	72	18.51	+1.53	125	41,630	w.	31	sw.	120	113	133	5.5	37.5
Cheyenne	6,088	24.00	30.00	+.03	44.7	−0.2	89	57	−14	32	103	27	56	19.09	+5.47	99	89,490	nw.	52	nw.	136	165	65	4.5	36.7
Lander	5,372	24.65	30.05	+.05	41.6	−0.5	93	56	−21	27	114	27	64	19.22	+3.50	79	30,562	sw.	42	s.	118	180	68	4.7	68.8
Sheridan, Wyo	.....	26.09	30.02	.....	43.7	.....	100	58	−20	30	120	20	66	16.98	.....	96	57,341	nw.	50	nw.	150	111	105	4.7	36.7
Yellowstone Park	6,200	23.88	30.07	+.06	38.2	−1.2	88	49	−26	27	114	26	67	19.64	−3.45	140	67,587	sw.	44	nw.	96	109	161	5.9	89.6
North Platte	2,821	27.08	30.03	+.04	50.1	+1.9	98	64	−9	36	107	36	68	19.96	+1.08	80	72,300	se.	47	nw.	192	103	71	4.0	15.3
Middle Slope.					55.0	+1.4							63	23.88	+6.08									4.9	
Denver	5,291	24.72	29.99	+.03	50.2	+0.4	92	63	−9	37	101	29	52	15.92	+1.83	77	64,961	s.	52	n.	152	174	40	4.2	39.6
Pueblo	4,685	25.28	29.97	+.02	52.2	+1.2	99	67	−8	38	107	27	47	6.14	−5.83	48	65,279	nw.	59	nw.	211	127	28	3.2	9.8
Concordia	1,398	28.54	30.02	+.01	54.5	+1.9	98	65	1	44	97	43	72	41.88	+14.37	97	65,764	s.	52	w.	107	197	62	4.9	8.2
Dodge	2,509	27.39	30.00	+.02	55.7	+2.3	101	69	−1	43	102	40	65	19.61	−1.27	80	91,069	se.	52	nw.	193	122	51	3.8	14.9
Wichita	1,358	28.60	30.04	+.03	57.2	+1.6	99	68	5	47	94	44	68	37.71	+7.05	84	93,984	s.	56	sw.	118	170	76	5.0	2.0
Oklahoma	1,214	28.72	30.00	.00	59.9	+1.2	97	70	10	50	87	48	72	52.03	+20.29	99	135,379	s.	62	sw.	119	154	93	5.0	0.5
Southern Slope.					62.3	+0.8							61	20.42	−1.95									4.2	
Abilene	1,738	28.20	30.00	+.02	64.7	+1.7	102	75	15	54	87	48	62	34.97	+10.17	77	75,080	s.	48	w.	117	159	90	5.1	.....
Amarillo	3,676	26.27	29.98	+.02	56.8	+1.7	97	70	4	44	93	40	64	19.05	−3.54	55	108,883	s.	62	sw.	267	78	19	3.3	24.4
Del Rio	944	29.00	29.99	+.03	69.2	+0.6	104	81	17	57	87	.....	.....	18.02	−8.28	65	68,905	e.	45	nw.	167	124	75	4.4	
Roswell	3,578	26.37	29.99	+.06	58.6	−0.9	101	74	12	43	89	38	58	9.62	−6.16	52	53,160	s.	42	sw.	163	142	52	4.2	2.4
Southern Plateau.					58.9	−0.6							47	12.45	−0.77									3.9	
El Paso	3,762	26.19	29.93	+.04	62.9	0.0	101	75	31	50	80	32	39	6.94	−2.91	41	100,582	w.	68	nw.	202	128	36	3.2	
Santa Fe	7,013	23.26	29.96	+.03	47.8	−1.0	86	60	−1	36	87	28	58	12.79	−1.73	85	79,086	ne.	44	nw.	212	125	29	3.2	24.0
Flagstaff	6,907	23.36	29.95	+.04	43.9	−0.8	84	58	−14	29	98	28	62	25.91	+2.88	86	68,334	sw.	58	sw.	181	98	87	4.1	69.2
Phoenix	1,108	28.76	29.91	+.03	69.1	−0.3	111	83	30	55	81	37	38	10.68	+2.78	42	37,933	e.	36	nw.	211	134	21	2.9	
Yuma	141	29.76	29.91	+.03	71.0	−1.1	114	86	28	56	86	42	43	5.93	+2.81	21	58,512	n.	40	sw.	318	29	19	1.3	
Middle Plateau.					48.6	−0.5							54	12.69	+1.17									4.1	
Reno	4,532	25.48	30.02	+.03	49.6	+0.5	100	64	−1	35	101	28	52	5.42	−5.07	50	46,001	w.	45	sw.	196	106	64	3.6	11.6
Tonopah, Nev	.....	24.08	30.04	.....	49.4	+3.4	94	59	7	40	87	24	45	5.30	−4.88	41	81,444	se.	52	nw.	182	134	41	3.6	
Winnemucca	4,344	25.64	30.05	+.04	48.2	−0.6	100	64	−5	32	105	30	58	6.42	−2.01	45	51,794	ne.	44	sw.	192	92	82	3.8	16.1
Modena	5,479	24.62	29.99	+.04	46.7	−1.8	96	61	−17	32	113	30	61	16.62	+6.44	64	90,372	w.	68	sw.	150	121	95	4.6	45.9
Salt Lake City	4,366	25.63	30.01	+.02	50.1	−1.7	95	60	6	40	89	32	56	20.85	+4.76	91	50,563	se.	40	nw.	156	127	83	4.5	48.7
Durango	6,546	23.67	30.00	+.06	45.2	−1.8	89	60	−5	30	94	26	57	24.00	+7.28	109	51,296	nw.	36	s.	138	169	59	4.4	73.1
Grand Junction	4,608	25.40	29.99	+.03	51.0	−1.5	98	64	−6	38	104	27	49	10.23	+1.70	64	45,175	nw.	42	s.	197	108	61	3.9	15.0
Northern Plateau.					50.0	+0.5							60	11.77	−3.08									5.2	
Baker City	3,471	26.47	30.08	+.04	46.2	+1.6	102	57	−4	35	106	33	64	8.61	−4.64	91	58,100	se.	32	s.	127	138	101	4.8	26.3
Boise	2,739	27.20	30.07	+.03	51.0	+0.4	104	62	5	40	99	32	55	12.33	−0.42	87	50,753	nw.	42	sw.	125	93	146	5.6	8.5
Lewiston	757	29.24	30.05	+.02	53.3	+0.1	103	64	7	42	101	.....	.....	10.91	−2.61	103	49,182	e.	56	w.	94	97	175	6.0	0.7
Pocatello	4,477	25.51	30.06	+.04	46.9	−0.7	96	58	−18	36	114	29	58	15.07	+2.10	103	74,018	se.	48	sw.	152	144	70	4.3	31.1
Spokane	1,929	27.98	30.05	+.03	48.7	+0.9	101	58	−4	39	105	33	63	12.02	−6.87	102	53,396	sw.	39	sw.	96	136	134	5.8	19.9
Walla Walla, Wash.	.....	28.98	30.06	+.02	54.2	+0.8	105	64	2	44	103	38	62	11.66	−6.05	96	52,036	s.	38	s.	143	112	111	5.0	9.2
N. Pac. Coast Region.					50.3	0.0							79	33.55	−6.43									6.2	
North Head		29.85	30.08	+.04	49.3	−0.6	79	53	26	46	53	45	87	45.02	−0.95	194	144,288	nw.	85	se.	71	103	192	6.9	
Port Crescent	211	29.79	30.08	+.07	45.8	−0.4	86	52	18	39	68	.....	.....	43.02	−0.64	162	44,375	nw.	36	sw.	59	152	155	6.4	0.6
Seattle	259	29.96	30.09	+.07	50.9	+0.1	88	58	25	44	63	44	81	28.25	−3.44	137	71,043	se.	50	s.	62	136	168	6.6	3.0
Takoma	123	29.84	30.06	+.03	50.4	0.0	90	58	23	43	67	43	79	38.21	−7.20	142	49,892	nw.	38	e.	99	106	161	6.2	2.0
Portland, Oreg.	153	29.92	30.08	+.03	52.9	+0.5	94	61	23	45	71	43	74	34.37	−10.95	151	55,431	nw.	33	s.	103	109	148	5.8	1.9
Roseburg	510	29.53	30.09	+.03	52.7	+0.1	102	64	23	41	79	43	76	24.18	−10.41	131	27,549	nw.	30	sw.	127	125	114	5.1	0.3
Mid. Pac. Coast Region.					56.9	−0.2							69	30.32	−6.57									4.0	
Eureka	62	30.03	30.10	+.03	50.7	−0.6	72	56	30	45	42	46	86	33.40	−12.89	116	63,502	n.	48	n.	125	133	108	5.2	
Mount Tamalpais	2,375	27.56	30.04	+.01	55.1	.....	96	62	31	49	65	39	63	25.13	+2.21	81	150,508	nw.	77	nw.	236	58	72	3.2	2.1
Red Bluff	332	29.64	29.99	−.00	62.2	−0.3	114	74	25	50	89	40	54	17.92	−7.24	52	50,920	nw.	40	n.	194	78	94	3.9	T.
Sacramento	69	29.93	30.00	+.01	59.7	+0.1	103	71	28	48	75	45	64	11.21	−8.97	54	71,257	s.	38	sw.	240	79	57	3.1	
San Francisco	155	29.87	30.04	+.02	55.0	+0.1	89	61	35	49	54	46	77	16.42	−5.97	70	69,916	w.	34	sw.	155	132	79	4.4	
S. Pac. Coast Region.					60.5	+0.1							67	11.17	−2.78									3.4	
Fresno	330	29.64	30.00	+.03	62.9	−0.3	114	77	29	49	85	39	54	7.08	−2.65	35	42,744	nw.	24	nw.	242	56	68	3.0	
Los Angeles	338	29.63	29.99	+.01	61.9	+1.6	96	72	37	52	59	47	68	13.74	−2.00	35	48,167	sw.	40	nw.	263	89	74	3.8	
San Diego	87	29.90	29.99	+.01	59.9	−0.7	84	66	37	54	47	50	73	8.59	−1.49	41	51,902	nw.	35	s.	277	46	43	2.9	
San Luis Obispo	201	29.82	30.04	+.02	57.2	0.0	96	69	28	46	68	45	72	15.28	−5.33	52	43,981	nw.	26	w.	204	97	65	3.8	
West Indies.																									
San Juan	82	29.91	29.99	+.01	78.5	.....	92	84	64	73	28	71	79	57.77	+3.18	216	93,979	e.	50	se.	160	151	55	4.3	

* Pressure reduced to standard gravity and to the mean of 24 hourly observations.

† For the snow year, July 1, 1907, to June 30, 1908.

TABLE II.—*Total number of days with thunderstorms at selected stations, 1908.*

States and stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Alabama.													
Anniston	1	0	3	5	13	12	18	14	3	0	1	1	71
Birmingham	0	1	2	5	11	10	18	11	1	0	1	1	61
Mobile	2	1	3	10	7	16	16	9	9	1	1	0	75
Montgomery	2	1	2	8	8	12	13	8	3	2	2	0	61
Scottsboro	2	0	0	1	3	1	6	0	0	0	0	0	13
Arizona.													
Flagstaff	0	0	0	3	2	1	21	20	7	1	0	0	55
Phoenix	0	0	0	1	1	1	16	12	4	0	1	3	39
Pinto	0	0	0	0	0	1	3	6	0	1	0	0	11
Yuma	0	0	0	0	0	0	0	2	1	0	0	0	3
Arkansas.													
Bentonville	0	4	0	7	13	14	8	10	4	2	5	0	67
Little Rock	1	4	5	7	6	6	12	11	5	0	6	0	63
Fort Smith	1	2	1	3	10	9	6	8	3	1	6	0	50
California.													
Eureka	0	1	0	0	0	0	0	0	0	1	0	0	2
Fresno	1	0	0	0	0	0	0	0	1	0	1	0	3
Independence	0	0	0	0	0	1	6	7	4	0	0	0	18
Los Angeles	1	1	0	0	0	0	0	1	3	1	0	0	7
Mount Tamalpais	0	1	0	0	0	0	0	0	0	0	0	0	1
Point Reyes Light	0	0	0	0	0	0	0	0	0	0	0	0	0
Red Bluff	0	0	0	0	2	0	0	0	0	0	0	0	2
Sacramento	0	0	1	0	0	0	0	0	1	0	0	0	2
San Diego	1	0	0	0	0	0	1	1	2	2	0	0	6
San Francisco	0	1	0	0	0	0	0	0	0	0	0	0	1
San Jose	0	0	0	0	0	0	0	0	0	0	0	0	0
San Luis Obispo	2	0	0	0	0	0	1	0	3	1	0	0	7
Southeast Farallon	0	1	0	0	0	0	0	0	0	0	0	0	1
Colorado.													
Denver	0	0	0	2	4	10	9	13	2	0	0	0	40
Durango	0	1	0	1	3	3	17	16	2	0	0	0	43
Grand Junction	0	0	0	3	2	4	7	10	2	0	0	0	28
Pueblo	0	1	1	3	4	6	18	8	1	1	0	0	43
Connecticut													
Hartford	0	0	2	2	2	2	11	6	1	0	0	0	26
New Haven	0	1	2	1	2	4	7	6	1	1	0	0	25
District of Columbia.													
Washington	2	0	1	1	6	4	11	4	2	0	0		31
Florida.													
Jacksonville	0	1	2	9	10	13	18	12	6	2	0	0	73
Jupiter	0	0	0	4	6	8	13	15	13	5	2	0	66
Key West	1	2	1	1	3	13	9	12	14	4	1	0	61
Myers	0	1	0	3	15	25	19	29	23	2	3	2	122
Pensacola	2	2	3	8	7	16	23	11	9	1	2	0	84
Sand Key	1	0	0	3	5	8	9	15	15	4	1	0	61
Tampa	1	1	0	4	6	16	13	22	9	1	0	0	73
Georgia.													
Atlanta	1	0	3	5	10	10	14	12	2	2	0	0	59
Augusta	1	0	3	6	9	9	16	9	0	1	0	0	54
Macon	3	0	3	8	7	7	11	12	1	1	0	1	54
Savannah	2	2	1	5	10	8	12	13	5	1	0	0	59
Thomasville	2	2	2	8	6	15	25	10	7	2	0	0	79
Idaho.													
Boise	0	0	0	1	1	3	6	2	4	0	0	0	17
Chesterfield	0	1	0	2	2	11	7	4	0	0	0	0	27
Lewiston	0	0	0	1	1	1	5	5	3	0	0	0	16
Murray	0	0	0	1	0	1	3	4	1	0	0	0	10
Pocatello	0	0	0	4	2	8	5	6	6	0	0	0	31
Illinois.													
Cairo	0	4	3	7	14	10	11	13	1	0	4	0	67
Chicago	0	1	5	3	7	7	8	5	3	0	2	0	41
Galva	0	0	2	2	4	6	4	3	3	0	4	0	28
La Salle	0	0	6	5	9	7	13	5	2	0	1	0	48
Peoria	0	1	5	4	13	10	12	6	1	0	2	0	54
Rantoul	0	1	6	6	11	7	7	4	2	1	2	0	47
Springfield	0	1	4	7	15	10	7	5	1	0	2	0	52
Indiana.													
Butlerville	0	1	9	2	8	5	4	1	0	0	3	0	33
Evansville	0	1	7	4	11	5	9	4	1	1	3	0	46
Indianapolis	0	1	5	3	7	6	7	4	0	1	3	0	37
Iowa.													
Charles City	0	0	2	2	11	11	4	3	1	1	0	0	35
Davenport	0	1	3	4	9	8	9	7	1	0	3	0	45
Des Moines	0	1	4	3	13	9	9	9	2	2	0	0	52
Dubuque	0	1	1	3	7	10	8	4	3	1	2	0	40
Keokuk	0	1	4	4	13	10	12	5	3	2	3	0	57
Sioux City	0	0	1	3	11	11	5	7	2	0	0	0	40
Kansas.													
Concordia	0	1	1	1	13	15	5	13	3	1	1	0	54
Dodge	0	0	0	4	7	12	7	3	2	3	0	0	38
Iola	0	2	1	8	9	11	10	7	3	3	4	0	58
Topeka	0	0	2	4	10	13	8	8	0	2	3	0	50
Wichita	0	0	0	3	10	14	8	9	5	2	2	0	53
Kentucky.													
Lexington	0	2	5	5	9	6	13	9	3	0	3	0	55
Louisville	1	2	7	5	7	7	10	6	2	0	4	0	51
Louisiana.													
New Orleans	2	4	2	5	4	10	17	11	11	0	0	0	66
Shreveport	1	3	0	7	9	9	9	7	5	0	6	0	56
Maine.													
Eastport	2	0	1	0	4	2	4	5	1	1	0	0	20
Farmington	0	0	0	0	4	2	5	2	1	0	0	0	14
Orono	0	0	0	0	4	0	5	3	0	0	0	0	12
Portland	0	0	1	0	5	0	6	4	1	0	0	0	17
Maryland.													
Baltimore	1	0	3	1	6	1	13	3	2	1	0	0	31
Grantsville	0	0	1	0	5	2	6	2	0	0	0	0	16
Princess Anne	0	0	0	2	3	3	9	5	2	1	0	0	25
Massachusetts.													
Boston	0	0	1	3	0	4	5	4	0	0	0	0	17
Nantucket	2	1	2	2	0	1	7	3	0	1	2	0	21

TABLE II.—*Total number of days with thunderstorms, etc.*—Continued.

States and stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Massachusetts—Con.													
Michigan.													
Alpena	0	0	2	3	7	5	5	2	2	0	2	0	28
Detroit	0	0	4	6	10	5	7	4	0	1	2	0	39
Escanaba	0	0	1	1	0	4	4	4	4	0	1	0	19
Grand Haven	0	0	1	5	8	4	8	5	1	0	3	0	35
Grand Rapids	0	0	1	6	7	5	6	5	1	0	1	0	32
Houghton	0	0	0	1	1	5	5	4	4	0	1	0	21
Marquette	0	0	1	1	2	6	4	3	3	1	1	0	22
Port Huron	0	0	2	2	5	8	4	5	0	1	2	0	29
Sault Sainte Marie	0	0	1	2	1	4	5	2	4	0	0	0	19
Minnesota.													
Collegeville	0	0	0	2	3	7	4	1	5	0	0	0	22
Duluth	0	0	0	0	5	9	7	3	6	0	0	0	30
Minneapolis	0	0	1	2	8	9	6	4	6	1	1	0	38
Moorhead	0	0	0	1	3	7	8	5	3	0	0	0	27
St. Paul	0	0	0	1	7	9	5	2	5	0	0	0	29
Mississippi.													
Meridian	1	2	1	5	6	9	14	9	5	0	1	0	53
Vicksburg	1	4	1	9	6	15	12	11	7	1	3	1	69
Missouri.													
Columbia	0	0	4	6	7	14	8	8	4	0	7	0	58
Hannibal	0	2	6	6	15	10	9	7	2	1	4	0	61
Kansas City	0	1	2	6	11	14	10	7	0	4	5	0	60
St. Louis	0	1	3	5	14	9	9	5	3	0	1	0	50
Springfield	0	3	3	6	9	12	5	9	2	0	4	0	53
Montana.													
Havre	0	0	0	1	3	9	5	7	5	0	0	0	30
Helena	0	0	0	2	3	8	6	4	6	0	0	0	29
Kalispell	0	0	0	0	5	3	6	3	2	0	0	0	17
Miles City	0	0	0	0	5	7	3	5	4	1	0	0	25
Ovando	0	0	0	0	0	0	0	0	0	0	0	0	0
Renova	0	0	1	1	1	0	1	2	1	0	0	0	7
Nebraska.													
Lincoln	0	0	2	5	11	15	6	13	3	1	0	0	56
North Platte	0	0	0	3	6	14	10	12	2	1	0	0	48
Omaha	0	0	2	4	14	14	8	10	0	1	1	0	54
Valentine	0	0	0	2	8	12	10	14	1	1	0	0	48
Nevada.													
Reno	0	0	0	1	0	4	7	4	2	0	0	0	18
Tonopah	0	0	0	0	0	0	8	5	4	0	0	0	17
Winnemucca	0	0	0	0	1	2	5	2	5	0	1	0	16
New Hampshire.													
Concord	0	0	1	2	4	3	3	5	0	0	0	0	18
Nashua	0	0	2	3	4	3	2	4	1	0	0	0	19
New Jersey.													
Atlantic City	0	0	1	3	3	3	7	2	2	1	0	0	22
Cape May	0	0	0	3	3	3	7	3	1	1	0	0	21
Somerville	1	0	2	1	5	4	11	4	3	2	0	0	33
New Mexico.													
Albert	0	0	0	3	2	0	1	3	1	0	0	0	10
Fort Wingate	0	0	0	0	0	1	4	13	1	0	0	0	19
Roswell	0	1	0	4	2	4	11	9	2	0	0	0	33
Santa Fe	0	1	2	5	6	6	31	18	5	1	0	0	75
New York.													
Albany	0	0	1	4	3	5	9	7	1	1	0	0	31
Binghamton	0	0	2	3	5	4	10	5	2	3	0	0	34
Buffalo	0	1	3	1	6	4	8	6	3	1	0	0	33
Canton	0	0	2	2	6	3	5	5	2	0	1	0	26
New York	0	0	2	1	3	4	9	4	2	0	0	0	25
Oswego	0	0	4	1	6	6	5	6	3	1	0	0	31
Rochester	0	0	3	1	6	5	7	5	3	1	0	0	31
South Canisteo	0	0	1	3	6	5	8	7	1	1	0	0	32
Syracuse	0	0	4	1	6	6	8	7	3	1	0	0	36
North Carolina.													
Asheville	1	1	2	2	11	9	14	14	0	2	0	0	56
Brewers	1	0	1	2	6	6	12	10	0	1	1	1	41
Charlotte	1	0	3	3	5	7	14	14	1	1	0	0	49
Hatteras	1	1	3	3	4	7	3	9	1	2	0	0	34
Raleigh	0	0	3	3	4	7	13	7	2	0	1	1	41
Wilmington	0	0	4	6	9	9	8	12	3	1	0	0	52
North Dakota.													
Bismarck	0	0	0	1	2	4	4	8	2	2	0	0	23
Devils Lake	0	0	0	0	4	7	8	9	2	0	0	0	30
Fullerton	0	0	0	2	4	4	6	5	3	1	0	0	25
Williston	0	0	0	1	4	7	4	5	2	0	0	0	23
Ohio.													
Cincinnati	0	1	4	2	7	6	10	3	1	0	0	0	34
Cleveland	0	0	3	4	8	8	8	7	3	1	0	0	42
Columbus	0	1	7	2	7	6	11	4	1	0	0	0	39
Sandusky	0	0	5	11	7	10	6	3	0	0	1	0	46
Toledo	0	0	4	3	11	6	8	8	0	0	1	0	41
Oklahoma.													
Hobart	0	1	0	0	8	9	9	2	4	8	2	0	43
Oklahoma	0	3	1	9	10	13	6	9	4	5	1	0	61
Pawhuska	0	1	2	5	12	15	6	3	11	5	0	0	60
Oregon.													
Ashland	0	0	0	0	0	0	1	1	1	0	0	0	3
Astoria	0	0	0	0	0	0	0	0	0	0	0	0	0
Baker City	0	0	0	2	1	4	5	4	6	0	0	0	22
Portland	0	0	0	0	0	0	0	0	0	0	0	0	1
Roseburg	0	0	0	0	0	0	1	0	0	0	0	0	1
Pennsylvania.													
Erie	1	0	4	3	8	6	6	3	4	0	1	1	36
Harrisburg	1	0	3	2	6	5	12	5	1	2	0	0	37
Philadelphia	1	0	2	2	3	2	10	4	1	0	0	0	25
Pittsburg	2	0	4	3	9	9	14	7	1	0	0	0	49
Scranton	0	0	4	2	1	4	9	5	1	3	0	0	29
Wellsboro	0	0	5	1	8	5	9	5	1	1	1	0	36
Rhode Island.													
Block Island	0	0	4	0	0	4	5	1	0	0	1	0	15
Narragansett	0	0	2	0	0	4	5	3	0	0	0	0	14
Providence	0	0	1	2	0	4	6	6	0	0	0	0	20
South Carolina.													
Charleston	1	2	1	6	9	11	8	12	3	1	3	1	58

TABLE II.—*Total number of days with thunderstorms, etc.*—Continued.

States and stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
South Carolina—Con.													
Columbia	3	0	2	5	7	11	11	10	4	0	0	0	53
South Dakota.													
Huron	0	0	1	2	4	11	7	7	3	1	0	0	36
Pierre	0	0	1	2	4	9	11	9	0	1	0	0	37
Rapid City	0	0	0	1	1	6	9	7	3	1	0	0	28
Yankton	0	0	1	3	8	12	8	5	0	1	0	0	38
Tennessee.													
Chattanooga	2	1	3	3	7	10	18	13	5	0	2	0	64
Knoxville	1	0	5	2	8	6	14	9	2	1	3	0	51
Memphis	1	2	4	7	7	8	12	8	3	1	5	1	59
Nashville	0	2	2	4	8	7	12	8	3	0	3	0	49
Texas.													
Abilene	0	0	1	6	6	3	11	3	2	3	3	0	38
Amarillo	0	0	0	3	5	9	6	8	1	1	1	0	34
Corpus Christi	0	1	2	4	2	11	8	7	1	2	1	1	41
Del Rio	0	0	0	4	1	1	6	4	3	1	1	1	22
El Paso	0	0	1	2	1	1	10	13	0	0	0	0	28
Fort Worth	1	4	3	10	13	5	12	6	9	4	1	0	68
Galveston	0	6	1	5	2	5	16	8	7	0	1	1	52
Palestine	1	3	1	11	8	6	15	8	6	1	4	2	66
San Antonio	0	3	3	6	7	3	14	9	5	4	1	2	57
Taylor	1	5	2	4	9	4	10	8	6	3	2	2	56
Utah.													
Levan	0	0	0	0	4	6	8	9	4	0	0	0	31
Modena	0	0	0	0	1	2	14	13	3	0	0	0	33
Salt Lake City	0	0	0	3	2	7	6	10	5	0	0	0	33
Vermont.													
Burlington	0	0	1	2	6	6	4	5	0	0	0	0	24
Northfield	0	0	1	2	2	5	5	4	0	1	0	0	20
Jacksonville	0	0	2	1	1	1	10	5	1	2	0	0	23
Virginia.													
Cape Henry	0	0	2	3	9	3	5	6	2	0	1	1	32
Dale Enterprise	0	0	0	1	13	9	9	9	1	1	0	0	43
Lynchburg	0	0	1	3	5	7	7	6	0	0	0	0	29
Mount Weather	0	0	2	1	8	9	12	8	2	1	0	0	43
Norfolk	0	0	2	4	9	3	9	5	1	0	1	0	34
Richmond	0	0	0	4	6	4	12	6	1	1	0	0	34
Wytheville	1	0	1	1	2	7	9	1	1	0	0	1	24
Washington.													
North Head	0	0	0	0	0	0	0	0	0	0	1	0	1
Port Crescent	0	0	0	0	0	0	1	2	0	0	0	1	4
Seattle	0	0	2	0	1	1	2	2	0	0	0	0	8
Spokane	0	0	0	2	1	3	2	1	1	1	0	0	11
Tacoma	1	1	0	0	0	1	2	1	0	0	0	0	6
Tatoosh Island	0	0	0	0	0	0	0	1	0	0	0	0	1
Walla Walla	0	0	0	2	0	0	2	2	1	0	0	0	7
West Virginia.													
Elkins	1	0	4	1	14	8	14	4	3	0	0	0	49
Parkersburg	1	0	9	3	10	7	11	6	1	2	0	0	50
Upper Tract	0	0	0	0	8	5	13	2	1	0	0	0	29
Wisconsin.													
Green Bay	0	0	0	2	3	5	5	6	3	0	2	0	26
La Crosse	0	1	1	2	10	8	8	5	3	1	1	0	40
Madison	0	0	2	2	8	9	8	4	1	0	1	0	35
Milwaukee	0	0	2	5	6	8	5	4	0	1	1	0	32
Wyoming.													
Cheyenne	0	0	0	2	9	13	15	10	1	1	0	0	51
Griggs	0	0	0	1	5	11	5	8	1	0	0	0	31
Lander	0	0	0	2	0	7	2	5	4	0	0	0	20
Sheridan	0	0	0	2	5	9	5	5	3	0	0	0	29
Yellowstone Park	0	0	0	2	5	10	6	5	3	0	0	0	31

TABLE III.—*Annual climatological summary, Canadian stations, 1908.*

Stations.	Pressure.* Mean not reduced.	Pressure.* Mean reduced.	Pressure.* Departure from normal.	Temperature. Mean.	Temperature. Departure from normal.	Temperature. Mean maximum.	Temperature. Mean minimum.	Precipitation. Total.	Precipitation. Departure from normal.	Total depth of snowfall.†
	Ins.	*Ins.*	*Ins.*	°	°	°	°	*Ins.*	*Ins.*	*Ins.*
St. Johns, N. F	29.74	29.88	—.03	41.4	+0.9	48.3	34.4	44.16	—10.47	.....
Sydney, C. B. I.	29.91	29.95	+.01	43.3	+2.0	51.9	34.7	54.63	+ 4.35	80.0
Halifax, N. S	29.87	29.98	—.01	44.2	+5.1	53.1	35.4	55.95	— 1.08	62.8
Grand Manan, N. B	29.90	29.95	—.02	43.6	+0.8	50.5	36.8	40.81	— 6.44	31.8
Yarmouth, N. S	29.92	29.99	—.01	43.8	+0.6	51.2	36.4	45.65	— 4.68	53.2
Charlottetown, P. E. I	29.89	29.93	—.01	42.4	+1.4	49.8	34.9	42.40	+ 0.78	93.5
Chatham, N. B	29.90	29.92	—.02	41.3	+2.6	51.8	30.8	43.73	+ 2.44	81.0
Father Point, Que	29.89	29.91	—.02	35.8	+1.0	43.4	28.2	36.66	+ 3.67	96.8
Quebec, Que	29.63	29.96	—.02	39.4	+1.2	47.9	30.8	46.74	+ 5.02	161.5
Montreal, Que	.....	.....	.....	42.8	+1.3	.....	.....	42.98	+ 1.99	150.5
Rockliffe, Ont	29.37	29.9	.00	37.5	—0.7	49.1	25.9	24.26	— 6.20	.....
Ottawa, Ont	29.72	30.05	+.05	41.8	+1.2	51.4	32.3	32.92	+ 0.38	125.8
Kingston, Ont	29.71	30.03	+.02	44.0	+0.9	51.9	36.2	33.85	+ 1.04	57.1
Toronto, Ont	29.63	30.01	—.01	46.8	+2.6	55.8	37.7	29.62	+ 0.13	78.1
White River, Ont	.....	.....	.....	30.9	—1.2	.....	.....	30.71	+ 5.92	.....
Port Stanley, Ont	29.38	30.02	—.01	45.9	+1.2	54.4	37.4	28.89	— 5.53	64.8
Southampton, Ont	29.29	.....	.....	45.1	+2.7	53.7	36.5	27.83	— 6.38	.....
Parry Sound, Ont	29.30	30.00	.00	42.8	+2.6	53.0	32.7	40.23	+ 1.96	151.0
Port Arthur, Ont	29.25	29.97	—.03	36.5	+2.1	44.8	28.2	24.55	— 0.21	25.1
Winnipeg, Man	29.13	29.98	—.02	37.6	+4.5	48.0	27.1	21.44	+ 0.46	52.8
Minnedosa, Man	28.12	29.97	—.03	36.2	+4.6	47.4	25.0	16.76	+ 0.31	28.5
Qu'Appelle, Assin	.....	.....	.....	36.3	+3.0	.....	.....	17.73	+ 1.65	43.9
Medicine Hat, Alberta	.....	.....	.....	44.7	+4.4	.....	.....	10.22	— 3.58	12.0
Swift Current, Sask	27.38	29.98	—.01	39.8	+2.3	50.9	28.6	12.60	— 2.87	48.4

TABLE III.—*Annual climatological summary*—Continued.

Stations.	Pressure.* Mean not reduced.	Pressure.* Mean reduced.	Pressure.* Departure from normal.	Temperature. Mean.	Temperature. Departure from normal.	Temperature. Mean maximum.	Temperature. Mean minimum.	Precipitation. Total.	Precipitation. Departure from normal.	Total depth of snowfall.†
	Ins.	*Ins.*	*Ins.*	°	°	°	°	*I*	*Ins.*	*Ins.*
Calgary, Alberta	26.35	29.90	—.03	40.7	+3.5	53.1	28.3	20.68	+ 5.81	26.1
Banff, Alberta	25.24	29.97	+.04	36.8	+2.1	47.2	26.5	21.09	— 0.82	70.7
Edmonton, Alberta	.....	.....	.....	38.4	+2.8	.....	.....	17.88	+ 2.05	28.5
Prince Albert, Sask	.....	.....	.....	34.4	+3.9	.....	.....	20.26	+ 5.35	.....
Battleford, Sask	28.18	29.95	—.02	35.2	+2.5	46.6	23.8	15.72	+ 1.79	34.8
Kamloops, B. C	.....	.....	.....	46.5	—0.6	55.8	37.2	7.50	— 4.13	00.0
Victoria, B. C	29.95	30.05	+.05	50.0	+1.4	56.6	43.3	26.78	—11.36	00.0
Barkerville, B. C	25.63	29.96	+.06	37.2	+1.0	46.5	28.0	49.53	+15.97	.....
Hamilton, Bermuda	29.98	30.14	+.05	69.0	—0.7	74.5	63.5	53.66	— 8.25	00.0

* Pressure reduced to standard gravity and to the mean of 24 hourly observations. † For the snow year, July 1, 1907, to June 30, 1908.

TABLE IV.—*Heights of rivers referred to zeros of gages, 1908.*

Stations.	Highest water. Stage.	Highest water. Date.	Lowest water. Stage.	Lowest water. Date.	Annual range.
Milk River.	*Feet.*		*Feet.*		*Feet.*
Havre, Mont. (110)	16.3	June 9	3.6	Sept. 23, 24, Oct. 24–26	12.7
James River.					
Huron, S. Dak. (83)	6.5	Mar. 18	—0.2	Sept. 16–18, Oct. 3–4	6.7
Republican River.					
Clay Center, Kans. (7)	21.6	June 6	5.1	Jan. 13	16.5
Smoky Hill–Kansas River.					
Abilene, Kans	24.0	June 11	0.0	*	24.0
Manhattan, Kans. (7)	24.8	June 8	2.4	*	22.4
Topeka, Kans	28.0	June 9	5.6	*	22.4
Missouri River.					
Bismarck, N. Dak. (96)	15.1	June 19	1.3	Nov. 15	13.8
Pierre, S. Dak. (76)	11.4	June 22	—0.5	Dec. 1	11.9
Sioux City, Iowa (2)	15.2	June 23	2.9	Jan. 6–8	12.3
Blair, Nebr	15.9	June 26	2.3	Jan. 1–3	13.6
Omaha, Nebr. (*a*) (33)	19.1	June 25, 26	6.1	Feb. 1	13.0
St. Joseph, Mo	14.9	June 14, 15	—2.6	Jan. 20	17.5
Kansas City, Mo. (6)	30.2	June 15	3.6	Jan. 19	26.6
Glasgow, Mo	27.2	June 18	4.3	Feb. 5	22.9
Boonville, Mo	28.2	June 18	5.4	Jan. 21, 22	22.8
Hermann, Mo	25.0	June 20	4.0	Feb. 4, 5	21.0
Minnesota River.					
Mankato, Minn	21.2	June 26	1.6	Jan. 6	19.6
St. Croix River.					
Stillwater, Minn. (124)	14.8	July 1	2.2	Sept. 18–20	12.6
Red Cedar River.					
Cedar Rapids, Iowa	8.6	May 30	2.8	Sept. 26	5.8
Des Moines River.					
Des Moines, Iowa (*b*) (10)	14.8	June 25	1.9	Oct. 8–23	12.9
Illinois River.					
La Salle, Ill. (9)	28.8	Mar. 8	11.4	*	17.4
Peoria, Ill	22.2	Mar. 10	7.5	Oct. 16	14.7
Clarion River.					
Clarion, Pa	12.0	Feb. 15	—1.2	Oct. 27, 28	13.2
Conemaugh River.					
Johnstown, Pa. (7)	16.7	Mar. 19	0.3	*	16.4
Allegheny River.					
Warren, Pa	12.2	Feb. 15	—0.9	Nov. 27–30	13.1
Franklin, Pa	16.4	Feb. 16	—0.6	*	17.0
Parker, Pa	17.5	Feb. 16	—0.5	*	18.0
Freeport, Pa	28.4	Feb. 16	0.2	Sept. 21, 22, 25–28	28.2
Springdale, Pa	33.0	Feb. 16	5.0	Sept. 23	28.0
Cheat River.					
Rowlesburg, W. Va. (23)	11.0	Feb. 15	—0.8	Oct. 26	11.8
Youghiogheny River.					
Confluence, Pa. (49)	9.0	Mar. 9	—0.7	*	9.7
West Newton, Pa. (18)	16.5	Feb. 16	—0.2	*	16.7
Monongahela River.					
Weston, W. Va	10.6	Feb. 15	—3.5	Nov. 24–Dec. 11	14.1
Fairmont, W. Va	23.1	Mar. 9	9.9	Oct. 29–Nov. 11	13.2
Greensboro, Pa. (2)	22.0	Feb. 16	5.2	Oct. 14	16.8
Lock No. 4, Pa	28.5	Feb. 16	6.7	July 4, 5	21.8
Muskingum River.					
Zanesville, Ohio	26.3	Mar. 4	7.5	Oct. 4	18.8
Beverly, Ohio	24.7	Mar. 6	3.5	Sept. 4	21.2
Little Kanawha River.					
Glenville, W. Va	15.0	May 10	—3.4	Nov. 10	18.4
Creston, W. Va	16.2	Mar. 10	—1.9	Nov. 21–27	18.1
New–Great Kanawha River.					
Radford, Va	7.2	Jan. 13	0.2	Sept. 27, 28	7.0
Hinton, W. Va	12.0	Jan. 13, Feb. 16	1.2	*	10.8
Charleston, W. Va	29.9	Apr. 2	4.1	Nov. 5	25.8
Scioto River.					
Columbus, Ohio (5)	18.5	Feb. 15	1.6	*	16.9
Licking River.					
Falmouth, Ky	30.0	Apr. 1, 2	0.0	Sept. 19, 20, Oct. 20–23	30.0
Miami River.					
Dayton, Ohio (7)	13.3	Mar. 3	0.4	Oct. 16, 17	12.9
Kentucky River.					
Beattyville, Ky	30.0	Apr. 2	—0.4	Oct. 2–7	30.4
High Bridge, Ky	27.3	Apr. 2	8.4	Nov. 1–4	18.9
Frankfort, Ky	30.0	Apr. 2	3.2	Nov. 1–7	26.8

TABLE IV.—*Heights of rivers referred to zeros of gages, 1908*—Continued.

Stations.	Highest water. Stage.	Highest water. Date.	Lowest water. Stage.	Lowest water. Date.	Annual range.
Wabash River.	*Feet.*		*Feet.*		*Feet.*
Mount Carmel, Ill.	24.9	May 13	0.3	Sept. 12	24.6
Cumberland River.					
Burnside, Ky	25.4	Feb. 16	−1.0	Oct. 6–9	26.4
Celina, Tenn.	25.0	Apr. 4	0.3	Oct. 8, 9, Nov. 6–10	24.7
Carthage, Tenn	24.5	Feb. 17	−0.1	Oct. 11–13, Nov. 3–5	24.6
Nashville, Tenn	29.4	Feb. 16	6.5	Oct. 9	22.9
Clarksville, Tenn	34.7	Feb. 20	0.0	Oct. 12–Nov. 10	34.7
Powell River.					
Tazewell, Tenn.	10.2	Feb. 16	0.2	Oct. 6–10	10.0
Clinch River.					
Speers Ferry, Va	13.0	Apr. 2	−0.2	Sept. 28, Oct. 8	13.2
Clinton, Tenn.	21.6	Apr. 4	2.0	Oct. 5–8	19.6
South Fork of Holston River.					
Bluff City, Tenn.	8.9	Jan. 12	0.2	*	8.7
Holston River.					
Rogersville, Tenn	12.7	Apr. 3	1.4	Sept. 26–28, Oct. 5–9, 18–22	11.3
French Broad River.					
Asheville, N. C.	5.9	Jan. 12, Feb. 15	−0.4	Oct. 8	6.3
Little Tennessee River.					
McGhee, Tenn.	11.0	Feb. 16	2.4	Sept. 27, 28	8.6
Hiwassee River.					
Charleston, Tenn	15.6	Feb. 16	0.2	Oct. 8, 22	15.4
Tennessee River.					
Knoxville, Tenn	16.9	Jan. 13	0.3	Sept. 19–28, Oct. 9	16.6
Loudon, Tenn	13.0	Jan. 14; Feb. 16, 17	0.7	Oct. 5–10	12.3
Kingston, Tenn	15.4	Feb. 16	1.2	Sept. 26–Oct. 9	14.2
Chattanooga, Tenn.	24.8	Feb. 18	1.3	Oct. 7, 8	23.5
Bridgeport, Ala	19.9	Feb. 17	0.3	Oct. 1, 2, 8	19.6
Guntersville, Ala	27.1	Feb. 19	1.5	Oct. 3, 4, 7, 8, 11, 12, 25, 26	25.6
Florence, Ala	17.0	Feb. 19, 20	−0.1	Oct. 2, 4–7, 27, 28	17.1
Riverton, Ala	34.8	Feb. 20	7.4	Oct. 28	27.4
Johnsonville, Tenn	27.1	Feb. 22	0.7	Oct. 30	26.4
Ohio River.					
Pittsburg, Pa	30.0	Feb. 16	1.9	June 10	28.1
Davis Island Dam, Pa.	29.1	Feb. 16	4.7	Feb. 2, July 7	24.4
Beaver Dam, Pa.	41.3	Feb. 16	0.8	Sept. 27, 28, 30, Oct. 4	40.5
Wheeling, W. Va.	42.8	Feb. 17	0.0	Sept. 30–Oct. 9	42.8
Parkersburg, W. Va.	41.2	Feb. 18	−0.3	Oct. 7–10	41.5
Point Pleasant, W. Va.	45.7	Feb. 19	0.2	Oct. 2	45.5
Catlettsburg, Ky	52.9	Apr. 3	2.3	Oct. 22, Dec. 3	50.6
Portsmouth, Ohio	54.0	Apr. 3	1.4	Oct. 4, 5	52.6
Maysville, Ky	52.6	Apr. 4	2.2	Oct. 6	50.4
Cincinnati, Ohio	55.9	Apr. 4	2.8	Oct. 5–7	53.1
Madison, Ind	48.1	Apr. 5	2.5	Oct. 8, 9	45.6
Louisville, Ky	31.3	Apr. 5, 6	2.2	Dec. 4	29.1
Evansville, Ind	42.2	Apr. 8, 9	1.3	Oct. 11–16	40.9
Mount Vernon, Ind.	41.9	Mar. 16	1.3	Nov. 1–3	40.6
Paducah, Ky	40.9	Feb. 26	1.1	Nov. 1	39.8
Cairo, Ill.	45.6	Mar. 18	4.3	Oct. 17–19	41.3
St. Francis River.					
Marked Tree, Ark.	18.1	Mar. 10–12	0.8	Oct. 22–Nov. 10	17.3
Neosho River.					
Neosho Rapids, Kans	26.3	June 14	0.6	Jan. 27	25.7
Iola, Kans.	12.5	June 19	−2.8	Oct. 19, 20	15.3
Oswego, Kans.	21.7	Dec. 1	0.1	Oct. 18–20	21.6
Fort Gibson, Okla.	35.0	May 25	8.6	Sept. 4, 5	26.4
Canadian River.					
Calvin, Okla.	17.2	May 24	2.7	*	14.5
Black River.					
Blackrock, Ark	23.4	May 7	2.0	Oct. 21–Nov. 23	21.4
White River.					
Calicorock, Ark.	29.1	May 15	−0.4	*	29.5
Batesville, Ark	28.2	May 16	1.5	*	26.7
Clarendon, Ark	30.7	May 25	7.1	Nov. 22	23.6
Arkansas River.					
Wichita, Kans	4.4	Oct. 23	−2.3	Oct. 11, 14–22	6.7
Tulsa, Okla.	17.7	May 25	2.4	Aug. 13–19, 24	15.3
Webbers Falls, Okla.	31.0	May 26	4.6	Oct. 18–20	26.4
Dardanelle, Ark.	27.6	May 29	2.4	Feb. 12	25.2
Little Rock, Ark.	26.3	June 16, 17	3.4	Oct. 23	22.9
Yazoo River.					
Greenwood, Miss.	32.7	Feb. 26, 27	0.6	Nov. 1, 2	32.1
Yazoo City, Miss.	26.0	Mar. 24	−2.6	Nov. 8–17	28.6
Ouachita River.					
Camden, Ark.	36.6	May 19	3.4	Sept. 11	33.2
Monroe, La. (*c*)	35.6	May 22–25	−1.5	Nov. 1–10	37.1
Red River.					
Denison, Tex. (*d*)	32.5	May 26			
Arthur City, Tex.	43.2	May 28	6.3	Sept. 17	36.9
Fulton, Ark.	34.1	June 2	8.7	Nov. 21–28	25.4
Shreveport, La.	35.2	June 15	−0.5	Oct. 21, 22	35.7
Alexandria, La.	41.8	July 6	2.9	Sept. 24, 25, Oct. 25, 26	38.9
Mississippi River.					
Fort Ripley, Minn. (115)	11.0	June 11	3.0	Dec. 1	8.0
St. Paul, Minn. (116)	16.8	June 29	1.6	Dec. 4	15.2
Red Wing, Minn. (120)	11.6	July 1, 2	1.1	Nov. 18–21	10.5
Reeds Landing, Minn. (15)	10.3	July 1, 2	−0.5	Feb. 4–9	10.8
La Crosse, Wis. (34)	11.7	July 4	1.9	Sept. 23–26	9.8
Prairie du Chien, Wis. (116)	13.7	June 21; July 7, 8	2.0	Sept. 23–26	11.7
Dubuque, Iowa (34)	14.9	July 19	1.2	Dec. 7	13.7
Clinton, Iowa (*e*)	13.9	July 20			
Leclaire, Iowa (61)	8.6	July 20	0.0	Jan. 3	8.6
Davenport, Iowa (4)	12.2	July 20, 21	0.8	Dec. 9	11.4
Muscatine, Iowa	13.5	July 21, 22	1.5	Dec. 10	12.0
Galland, Iowa.	7.4	June 9	0.5	Jan. 11–13, 27, Dec. 11	6.9
Keokuk, Iowa.	15.0	May 29	−0.9	Jan. 19	15.9
Warsaw, Ill.	18.4	May 29	2.8	Jan. 10, 11	15.6
Hannibal, Mo. (11)	17.6	June 1	0.6	Jan. 19, 20	17.0
Grafton, Ill.	23.8	June 18, 19	3.0	Dec. 16	20.8

TABLE IV.—*Heights of rivers referred to zeros of gages, 1908*—Continued.

Stations.	Highest water. Stage.	Highest water. Date.	Lowest water. Stage.	Lowest water. Date.	Annual range.
Mississippi River—Cont'd.	*Feet.*		*Feet.*		*Feet.*
St. Louis, Mo.	34.9	June 20, 21	1.7	Feb. 4	33.2
Chester, Ill.	30.7	June 20–23	3.6	Dec. 26	27.1
New Madrid, Mo.	36.6	Mar. 20, 21	3.7	Oct. 18–20, 27, 28	32.9
Memphis, Tenn.	35.6	Mar. 23–25	3.5	Oct. 30, 31	32.1
Helena, Ark	45.2	Mar. 26, 27	3.9	Oct. 30, 31, Nov. 1	41.3
Arkansas City, Ark	49.9	June 2–4	3.4	Oct. 24, 25	46.5
Greenville, Miss	44.7	June 2–5	2.3	Oct. 25, 26	42.4
Vicksburg, Miss	47.9	June 6–10	2.0	Oct. 25–28	45.9
Natchez, Miss.	48.9	June 14	4.9	Oct. 28, 29	44.0
Baton Rouge, La	39.6	June 15–17	3.5	Oct. 30, 31	36.1
Donaldsonville, La.	31.6	June 16, 18, 19	3.0	Nov. 23, Dec. 4	28.6
New Orleans, La.	20.0	June 19, 22	3.3	Nov. 22, Dec. 4	16.7
Atchafalaya River.					
Simmesport, La.	45.2	June 19	0.4	Oct. 31	44.8
Melville, La.	39.7	June 22, 23	5.0	Oct. 29, 30	34.7
Morgan City, La. (*f*)	6.0	June 19	1.5	Jan. 14	4.5
Grand River.					
Grand Rapids, Mich.	15.2	Mar. 16	1.6	Oct. 18	13.6
Maumee River.					
Tiffin, Ohio.	7.2	Mar. 4	−0.3	Nov. 11–15	7.5
Connecticut River.					
Hartford, Conn.	18.5	Feb. 18	0.2	Nov. 23	18.3
Mohawk River.					
Utica, N. Y.	13.4	Feb. 16	0.6	Sept. 19–28, Oct. 26, 27	12.8
Tribes Hill, N. Y.	8.0	Feb. 16	−0.5	*	8.5
Schenectady, N. Y.	9.5	Feb. 16; Mar. 30	0.2	July 3, 4	9.3
Hudson River.					
Glens Falls, N. Y. (*g*)	8.4	May 3	2.9	Aug. 31	5.5
Troy, N. Y.	18.2	Feb. 16	1.4	Nov. 5	16.8
Albany, N. Y.	16.7	Feb. 16	0.8	Nov. 2, Dec. 3	16.4
Pompton River.					
Pompton Plains, N. J.	6.9	Feb. 16	3.3	Sept. 26–28, Dec. 15–17	3.6
Passaic River.					
Chatham, N. J. (54)	6.0	Feb. 28	2.1	*	3.9
Lehigh River.					
Mauch Chunk, Pa. (62)	8.5	Feb. 16	3.5	Dec. 5	5.0
Schuylkill River.					
Reading, Pa.	6.6	Feb. 27	0.3	June 10–15, 22–24	6.3
Delaware River.					
Hancock, N. Y. (E. Br.)	10.7	Feb. 16	2.3	Sept. 18–23, 26–28	8.4
Hancock, N. Y. (W. Br.)	10.3	Feb. 16	2.2	*	8.1
Port Jervis, N. Y.	13.5	Feb. 16	0.9	Aug. 18	12.6
Phillipsburg, N. J. (78)	14.2	Feb. 16	−0.3	Sept. 20–28	14.5
Trenton, N. J.	10.0	Feb. 16, 17	0.1	Sept. 24–28	9.9
North Br. Susquehanna River.					
Towanda, Pa.	14.5	Feb. 16	0.0	Sept. 21–28	14.5
Wilkes-Barre, Pa	21.8	Feb. 17	2.0	Sept. 17 28	19.8
West Br. Susquehanna.					
Renovo, Pa. (29)	13.4	Feb. 16; Mar. 20	−0.7	Dec. 6	14.1
Williamsport, Pa.	17.4	Mar. 20	0.2	Sept. 13–28	17.2
Juniata River.					
Huntingdon, Pa.	13.6	Mar. 19	2.4	Nov. 21	11.2
Susquehanna River.					
Harrisburg, Pa.	16.0	Mar. 20	0.2	Sept. 19–28	15.8
Shenandoah River.					
Riverton, Va.	18.0	Jan. 13	−1.3	Sept. 23–28	19.3
Potomac River.					
Cumberland, Md.	9.6	Mar. 9	1.6	Sept. 11–30, Oct. 1–25	8.0
Harpers Ferry, W. Va.	19.9	Jan. 13	−1.2	Sept. 23–27	21.1
James River.					
Buchanan, Va	18.4	Jan. 12	2.0	Sept. 25–28, Oct. 8, 9	16.4
Lynchburg, Va.	16.2	Jan. 13	0.4	Oct. 15–23	15.8
Columbia, Va.	26.1	Feb. 16	3.2	Aug. 23–25	22.9
Richmond, Va	13.9	Feb. 17	−0.2	Apr. 12, Oct. 21–23	14.1
Dan River.					
Danville, Va.	9.5	Aug. 26	−0.2	*	9.7
Staunton River.					
Randolph, Va. (*h*)	24.8	Jan. 9	4.3	Aug. 4	20.5
Roanoke River.					
Clarksville, Va	13.6	Aug. 26	−0.1	Aug. 20, Oct. 10	13.7
Weldon, N. C	45.4	Aug. 28	10.1	July 22	35.3
Tar River.					
Tarboro, N. C	28.0	Sept. 1	1.7	July 26	26.3
Greenville, N. C.	19.4	Sept. 2	3.3	July 27	16.1
Haw River.					
Moncure, N. C.	34.3	Aug. 26	1.3	Sept. 21–23	33.0
Cape Fear River.					
Fayetteville, N. C	68.7	Aug. 29	3.0	July 19	65.7
Waccamaw River.					
Conway, S. C	10.2	Sept. 10	1.9	June 26	8.3
Pedee River.					
Cheraw, S. C. (*i*)	44.3	Aug. 27	1.6	Oct. 9	42.7
Smiths Mills, S. C.	24.0	Sept. 3, 4	3.0	Aug. 19	21.0
Lynch Creek.					
Effingham, S. C	20.0	Aug. 30	3.1	July 24	16.9
Black River.					
Kingstree, S. C.	10.0	Jan. 15–17, 19–21; Feb. 18, 19	0.0	Oct. 18–22	10.0
Catawba–Wateree River.					
Mount Holly, N. C.	14.2	Aug. 26	1.8	*	12.4
Catawba, S. C.	28.4	Aug. 25	1.3	Oct. 4	27.1
Camden, S. C.	39.7	Aug. 26	5.3	July 20	34.4
Broad River.					
Blairs, S. C.	31.1	Aug. 27	0.1	*	31.0
Saluda River.					
Chappels, S. C	34.7	Aug. 26	2.0	Oct. 19, Nov. 24	32.7
Congaree River.					
Columbia, S. C.	35.8	Aug. 27	0.4	Aug. 16	35.4
Broad River.					
Carlton, Ga.	29.0	Aug. 25	2.2	Aug. 2–4	26.8

TABLE IV.—*Heights of rivers referred to zeros of gages, 1908*—Continued.

Stations.	Highest water. Stage.	Highest water. Date.	Lowest water. Stage.	Lowest water. Date.	Annual range.
Savannah River.	Feet.		Feet.		Feet.
Calhoun Falls, S. C.	28.2	Aug. 25	1.9	Oct. 13, 14, 22	26.3
Augusta, Ga	38.8	Aug. 27	6.9	Aug. 18	31.9
Oconee River.					
Milledgeville, Ga.	33.2	Aug. 27	2.8	Mar. 11	30.4
Dublin, Ga	23.2	Aug. 30	— 0.2	Oct. 7	23.4
Ocmulgee River.					
Macon, Ga.	20.4	Apr. 27	1.7	Oct. 6	18.7
Abbeville, Ga	17.5	May 2	1.4	Oct. 9	16.1
Flint River.					
Woodbury, Ga.	9.5	Apr. 27	0.1	Aug. 15–18	9.4
Montezuma, Ga	23.2	Apr. 29	1.7	Sept. 22	21.5
Albany, Ga	27.9	May 3	0.6	Oct. 18–20, 23–27	27.3
Bainbridge, Ga.	25.6	May 6	4.6	Oct. 21–30	21.0
Chattahoochee River.					
Westpoint, Ga	15.8	Apr. 26	1.7	Oct. 1, 3–8	14.1
Eufaula, Ala.	47.0	Apr. 29	0.5	Sept. 20, Oct. 4–8	46.5
Alaga, Ala.	38.2	Apr. 30	2.1	Oct. 6	36.1
Coosa River.					
Rome, Ga	22.0	Mar. 25	0.0	Oct. 27	22.0
Gadsden, Ala	20.8	Feb. 17	0.2	Oct. 2–9	20.6
Lock No. 4, Ala.	17.3	Feb. 15	0.1	Oct. 2–8	17.2
Wetumpka, Ala.	37.9	Feb. 17	0.7	Oct. 8	37.2
Tallapoosa River.					
Mil ead, Ala	35.6	Apr. 28	0.6	Oct. 8	35.0
Alabama River.					
Montgomery, Ala.	37.4	Feb. 17	— 0.4	Oct. 7, 8	37.8
Selma, Ala	43.9	Feb. 20	— 0.9	Oct. 6–8	43.9
Black Warrior River.					
Tuscaloosa, Ala.	52.7	Mar. 25	4.3	Sept. 19	48.4
Tombigbee River.					
Columbus, Miss.	23.2	Feb. 20	— 3.3	Sept. 18–22	26.5
Vienna, Ala	36.0	Feb. 23	0.6	Nov. 16–21	35.4
Demopolis, Ala	52.1	Feb. 26	— 2.6	Oct. 7	54.7
Pascagoula River.					
Merrill, Miss.	21.4	Feb. 20, 21	0.5	Oct. 21, 23	20.9
Pearl River.					
Columbia, Miss.	21.0	May 11	2.8	*	18.2
Sabine River.					
Logansport, La.	32.9	May 18	1.6	*	31.3
Neches River.					
Rockland, Tex	25.0	May 25	0.4	Aug. 17–20, Oct. 21, 27–29	24.6
Beaumont, Tex	7.3	June 1	0.3	Dec. 22	7.0
Trinity River.					
Dallas, Tex	52.6	May 25	4.1	Oct. 13, 18	48.5
Long Lake, Tex.	51.8	June 4	2.0	Jan. 30	49.8
Riverside, Tex	49.7	June 11	0.8	Sept. 16–18	48.9
Liberty, Tex.	28.1	June 17–20	4.7	Oct. 25	23.4
Brazos River.					
Kopperl, Tex.	34.0	May 24	— 0.5	Mar. 31	34.5
Waco, Tex.	36.7	May 25	1.4	Nov. 23–28	35.3
Valley Junction, Tex.	50.9	May 27	2.3	Oct. 22	48.6
Hempstead, Tex.	42.6	June 2	— 0.2	Dec. 8	42.8
Booth, Tex	42.3	June 6, 7	4.2	Nov. 7, 8	38.1
Colorado River.					
Ballinger, Tex.	18.2	Apr. 19	0.0	Feb. 18–26	18.2
Austin, Tex	22.0	Aug. 23	1.0	Apr. 10	21.0
Columbus, Tex.	35.8	Apr. 27	5.8	Feb. 2–8	30.0
Guadalupe River.					
Gonzales, Tex.	20.5	May 27	0.4	*	20.1
Victoria, Tex	21.1	May 29	0.8	Oct. 7, 8	20.3
Red River of the North.					
Moorhead, Minn. (b2)	14.7	June 13	6.2	Nov. 13	8.5
Snake River.					
Lewiston, Idaho.	14.1	June 15, 16	0.7	Aug. 14, 15, 19, 20	13.4
Riparia, Wash.	13.7	June 17	1.2	Sept. 1–4	12.5
Columbia River.					
Wenatchee, Wash.	41.0	June 18	3.0	Feb. 5–7	38.0
Umatilla, Oreg.	21.9	June 17, 18	0.1	Feb. 9–11	21.8
The Dalles, Oreg.	37.1	June 18	— 0.5	Feb. 5	37.6
Willamette River.					
Albany, Oreg.	10.5	Jan. 1	0.7	Sept. 28–Oct. 2	9.8
Salem, Oreg	17.8	Mar. 17	— 0.2	Sept. 29–Oct. 13	18.0
Portland, Oreg.	21.2	June 20, 21	0.5	Nov. 16	20.7
Sacramento River.					
Red Bluff, Cal.	22.0	Feb. 10	0.5	Aug. 29–Sept. 16	21.5
Sacramento, Cal.	20.4	Feb. 13	5.3	*	15.1

Figures in parenthesis indicate number of days river was frozen during the year.
(*a*) No readings for January. * Various dates.
(*b*) No readings from January 19 to May 17, inclusive.
(*c*) No readings from January 7 to February 15, inclusive.
(*d*) No readings from June to December, inclusive.
(*e*) No readings from August to January, inclusive, of each year.
(*f*) No readings from October 20 to November 25, inclusive.
(*g*) No readings from June 1 to 10, inclusive.
(*h*) No readings for December. (*i*) No readings from September 1 to 22, inclusive.

TABLE V.—*Average monthly and annual departures of temperature from the normal, during 1908.*

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
New England	+ 2.3	— 3.1	+1.6	—0.6	+1.5	+1.2	+2.1	—0.9	+2.1	+2.6	+1.1	0.0	+0.8
Middle Atlantic	+ 1.3	— 3.7	+4.6	+2.7	+1.1	+0.1	+1.2	—1.1	+0.2	+2.0	+1.6	+1.2	+0.9
South Atlantic	0.0	— 3.9	+6.4	+4.8	+1.2	—0.5	+0.2	+0.1	—1.0	—1.3	+3.0	+4.0	+1.1
Florida Peninsula	+ 1.0	— 3.0	+3.5	+5.6	+1.0	—0.4	—0.2	—0.3	—0.1	—1.8	+0.7	+4.2	+0.8
East Gulf	— 0.1	— 3.3	+7.1	+4.3	+0.4	0.4	—0.2	+0.8	+0.4	—2.8	+3.9	+4.6	+1.3
West Gulf	+ 3.5	+ 1.1	+6.5	+1.5	+0.4	+0.7	—1.0	+0.4	+0.1	—1.8	+2.9	+3.5	+1.5
Ohio Valley and Tennessee	+ 0.8	— 1.6	+6.4	+1.7	+1.1	—0.4	+0.3	+0.5	+2.9	+0.5	+2.9	+2.2	+1.4
Lower Lakes	+ 1.4	— 3.3	+3.1	—0.3	+1.3	+0.4	+0.3	—1.1	+3.5	+2.0	+2.2	—0.1	+0.8
Upper Lakes	+ 4.0	+ 0.4	+2.6	+1.2	+1.1	+0.1	+0.6	+0.3	+5.6	+2.9	+3.6	—0.1	+1.9
North Dakota	+11.8	+ 8.0	+0.3	+3.0	—2.0	—1.6	+0.6	—3.2	+3.6	—0.7	+6.4	+1.4	+2.3
Upper Mississippi Valley	+ 5.3	+ 2.4	+5.0	+0.8	—0.3	—2.0	—0.9	—0.6	+4.5	+0.6	+4.1	+2.3	+1.8
Missouri Valley	+ 8.9	+ 4.9	+5.7	+2.4	—1.3	—2.3	—1.5	—1.1	+4.6	—0.5	+4.2	+4.0	+2.2
Northern Slope	+ 6.8	+ 3.7	+1.2	+3.3	—2.6	—3.7	+0.4	—2.4	+2.2	—1.5	+2.5	+1.3	+0.9
Middle Slope	+ 7.1	+ 5.2	+5.8	+0.9	—1.3	—1.1	—2.3	—0.8	+1.3	—1.5	—1.2	+3.0	+1.3
Southern Slope	+ 4.4	+ 2.8	+6.0	—0.6	—0.8	+0.2	—3.2	—0.8	—1.1	—2.0	0.0	+2.7	+0.6
Southern Plateau	+ 2.8	+ 0.2	+2.1	+0.6	—4.2	—2.3	—0.2	—0.7	—0.8	—4.2	—0.6	—0.4	—0.6
Middle Plateau	+ 2.8	+ 0.8	+1.7	+1.7	—5.6	—4.4	+0.9	—1.3	—0.8	—3.6	—0.4	—3.2	—1.0
Northern Plateau	+ 3.0	+ 3.0	+1.3	+2.0	—4.1	—2.5	+2.6	—0.7	+1.2	—1.2	+2.6	—1.9	+0.4
North Pacific	+ 2.5	+ 0.8	—0.2	0.0	—2.9	—1.1	+1.2	—1.2	—0.9	—0.6	+3.2	—1.5	—0.1
Middle Pacific	+ 1.7	— 0.9	+0.5	+2.0	—2.8	—2.7	+1.8	—1.0	+0.5	—1.2	+0.4	—3.8	—0.5
South Pacific	+ 2.5	— 0.6	+1.8	+2.5	—2.6	—2.4	+2.0	+0.4	+1.2	—0.6	—0.4	—2.3	+0.1

TABLE VI.—*Monthly and annual departures of precipitation from the normal, during 1908.*

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
New England	−0.6	+0.5	−0.9	−0.8	+0.8	−1.5	−0.7	+0.6	−2.1	−0.5	−2.5	+0.1	−7.6
Middle Atlantic	−0.1	+0.5	−0.9	−0.6	+1.5	−1.1	−0.1	+0.8	−1.0	−0.3	−1.9	−0.1	−3.4
South Atlantic	+0.3	−0.6	−0.6	−0.4	−0.5	−0.2	+0.6	+2.9	+0.1	+0.6	−1.4	−1.0	−0.2
Florida Peninsula	−0.2	−1.1	−2.8	+0.7	−1.1	+0.6	−0.8	+0.2	+2.8	+0.2	+0.4	−1.7	−2.8
East Gulf	+0.3	+0.1	−1.2	+1.2	+1.2	−1.7	+0.6	−1.0	−0.3	−1.2	−2.2	−1.2	−5.5
West Gulf	−1.1	+0.5	−0.9	+1.4	+3.3	−1.5	−0.5	+0.4	+1.2	−1.6	−0.7	−1.3	−0.1
Ohio Valley and Tennessee	−1.3	+0.6	+0.6	+0.8	+1.0	−2.0	−0.5	−0.4	−1.6	−1.8	−1.6	−0.8	−6.8
Lower Lakes	−0.7	+1.4	+0.3	+0.3	+0.4	−1.1	0.0	−0.4	−1.8	−1.5	−1.6	+0.9	−5.1
Upper Lakes	−0.5	+0.8	0.0	+0.6	+1.0	−1.1	−0.4	−0.1	−1.2	−1.8	−0.2	−0.6	−3.5
North Dakota	−0.4	+0.7	+0.4	−0.2	+0.5	−0.2	−0.2	+0.1	−0.4	+0.4	+0.4	−0.2	+0.9
Upper Mississippi Valley	−0.8	+0.9	−0.5	+0.5	+2.9	+0.1	−0.8	−0.3	−1.5	−1.3	−0.3	−0.9	−2.0
Missouri Valley	−0.5	+1.0	−0.6	−0.2	+1.2	+2.4	−0.4	+0.2	−1.8	+2.6	+0.9	−0.4	+4.4
Northern Slope	−0.3	−0.1	+0.1	−0.8	+2.2	+1.1	+0.1	+0.2	+0.1	+1.4	−0.5	−0.3	+3.2
Middle Slope	−0.3	+0.6	−1.1	−0.4	+1.1	+3.8	−0.4	+1.4	−0.1	+1.1	+0.8	−0.6	+5.9
Southern Slope	−0.2	−0.1	−0.7	+1.7	+2.2	+1.9	+0.3	−0.4	−0.1	+1.2	+0.4	−1.0	+5.2
Southern Plateau	−0.1	+0.4	−0.4	+0.3	0.0	−0.2	+0.5	+0.3	−0.3	−0.4	−0.4	−0.4	−0.7
Middle Plateau	−0.2	−0.1	−0.6	−0.6	+0.6	+0.2	+0.4	+0.7	+0.5	+0.6	−0.4	0.0	+1.1
Northern Plateau	−0.9	−0.4	−0.5	−0.6	+0.5	+0.5	+0.3	0.0	0.0	+0.4	−0.8	−0.9	−2.4
North Pacific	−1.2	−0.4	+0.2	−0.4	+0.3	−1.1	−0.3	+0.3	−1.8	+0.3	−1.2	−2.2	−7.5
Middle Pacific	+0.5	+0.6	−2.7	−1.9	−0.1	−0.3	0.0	0.0	−0.5	−0.1	−1.1	−1.9	−7.5
South Pacific	+1.3	+0.4	−2.0	−0.6	−0.3	−0.1	0.0	+0.2	+0.4	−0.6	−0.4	−1.2	−2.9

TABLE VII.—*Monthly and annual departures of relative humidity from the normal, during 1908.*

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
New England	− 6	− 1	0	− 4	0	− 6	− 6	− 2	− 3	− 1	− 4	− 4	− 3
Middle Atlantic	− 4	− 1	+ 6	+ 1	+ 4	− 3	+ 1	0	− 1	0	− 2	− 2	0
South Atlantic	− 1	− 2	+ 4	+ 2	+ 1	+ 1	+ 1	+ 1	0	+ 1	− 1	0	+ 1
Florida Peninsula	− 1	− 5	+ 4	+ 6	− 2	0	− 1	+ 2	+ 1	0	+ 1	+ 1	0
East Gulf	− 5	− 8	+ 7	+ 6	+ 4	− 2	+ 2	− 1	0	− 5	− 1	− 1	0
West Gulf	− 7	− 4	+ 5	+ 5	+ 2	0	+ 1	+ 3	+ 3	− 4	− 1	0	0
Ohio Valley and Tennessee	− 5	− 1	+ 1	+ 2	+ 6	− 3	+ 2	− 1	− 6	− 2	− 5	− 1	− 1
Lower Lakes	− 4	+ 1	0	0	+ 6	− 2	+ 1	− 2	− 7	− 6	− 5	− 1	− 2
Upper Lakes	− 5	− 2	− 2	− 1	+ 4	− 2	+ 1	− 2	− 3	− 2	0	− 2	− 1
North Dakota	− 1	+ 4	+ 2	− 2	+ 6	+ 3	− 4	− 2	− 1	+ 6	− 2	+ 9	+ 2
Upper Mississippi Valley	− 3	0	− 3	− 1	+ 5	+ 1	+ 4	0	− 2	− 3	− 2	− 4	− 1
Missouri Valley	− 8	0	− 4	− 3	+ 4	+ 6	+ 3	+ 2	− 3	+ 1	− 2	− 2	0
Northern Slope	− 1	+ 2	0	− 2	+11	+ 9	+ 6	+ 8	+ 3	+12	+ 2	+ 8	+ 5
Middle Slope	− 8	− 2	− 5	+ 2	+ 1	+ 3	+ 6	+ 7	+ 5	+ 4	+ 3	+ 1	+ 1
Southern Slope	− 4	− 8	− 3	+ 8	− 4	− 3	+11	+ 8	+ 4	− 2	− 2	− 4	0
Southern Plateau	+ 6	+10	+ 3	+12	+ 3	− 3	+ 8	+13	+ 2	− 7	+ 1	+15	+ 5
Middle Plateau	+ 4	− 1	− 4	+ 1	+ 5	+12	+ 7	+15	+ 9	+ 4	+ 1	+ 2	+ 5
Northern Plateau	− 2	0	− 5	− 7	+ 1	+ 2	+ 3	+ 5	− 1	+ 2	− 5	0	− 1
North Pacific	+ 1	+ 1	+ 2	+ 6	+ 3	+ 2	0	+ 1	− 2	+ 2	0	+ 1	+ 1
Middle Pacific	+ 3	+ 4	− 6	− 8	+ 1	+ 1	0	− 1	− 4	− 2	+ 1	+ 3	− 1
South Pacific	0	+ 5	− 7	− 3	− 2	− 1	− 3	0	0	− 9	+ 4	+ 1	+ 1

TABLE VIII.—*Monthly and annual departures of average cloudiness from the normal, during 1908.*

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
New England	−0.5	−0.1	+0.7	−0.2	+0.4	−1.5	−0.1	+0.2	−0.1	−0.5	+0.6	+0.7	0.0
Middle Atlantic	−0.3	+0.1	+0.6	−0.4	+0.8	−0.8	+0.5	+0.4	0.0	−0.2	−0.1	+0.9	+0.1
South Atlantic	−0.3	−0.4	−0.1	+0.7	0.0	−0.4	+0.4	+0.2	−0.1	+0.1	−0.6	+0.7	0.0
Florida Peninsula	−0.6	−0.9	−1.4	−0.9	−0.8	+0.4	−0.3	+0.6	+0.1	0.0	−0.6	−0.2	−0.4
East Gulf	0.0	−0.1	+0.3	+1.3	+0.4	−0.3	+1.2	+0.4	+0.9	−0.8	−0.2	+0.6	+0.3
West Gulf	−0.5	−0.8	+0.1	+0.4	−0.2	−0.4	+0.2	−0.3	+0.6	−0.8	0.0	+0.1	−0.1
Ohio Valley and Tennessee	−0.5	+0.7	+0.8	+0.5	+0.7	−0.2	+0.4	+0.1	−1.2	−0.7	−0.8	+0.4	0.0
Lower Lakes	−0.7	+0.1	+0.8	+0.5	+0.7	−1.4	−0.5	−0.5	−1.9	−1.2	−0.2	+0.1	−0.4
Upper Lakes	−0.8	+1.0	+0.8	+0.2	+0.9	−0.5	0.0	−0.4	−0.7	−0.5	−0.1	+0.6	0.0
North Dakota	+1.3	+1.0	+1.1	−0.5	+0.3	+0.4	−0.4	−0.2	−0.3	+1.0	+0.3	+0.2	+0.3
Upper Mississippi Valley	−0.4	+0.5	+0.5	−0.3	+0.8	+0.1	+0.6	+0.1	−0.9	+0.1	+0.1	−0.3	+0.1
Missouri Valley	−1.1	+0.2	+0.1	−0.3	−0.2	+0.7	+0.1	+0.1	−0.6	+1.1	−0.1	−0.6	0.0
Northern Slope	−0.2	+0.8	+0.6	−1.2	+0.6	−0.1	−0.7	+0.2	0.0	+1.3	0.0	+0.9	+0.2
Middle Slope	−0.4	+0.4	+0.4	+0.8	0.0	+0.8	+0.8	+0.8	−0.1	+1.0	+0.5	0.0	+0.4
Southern Slope	+0.5	+0.2	+0.7	+0.9	−0.7	−1.0	+1.4	−0.8	+0.3	+0.2	+0.7	+0.8	+0.3
Southern Plateau	+0.7	+1.0	+0.5	+0.4	+0.1	−0.6	+1.1	+0.2	0.0	−0.4	+1.0	+1.0	+0.3
Middle Plateau	+0.6	+0.2	−0.9	−1.2	+0.6	+0.4	+1.7	+1.2	+1.0	+0.7	−0.1	−0.3	+0.3
Northern Plateau	−0.7	−0.3	−0.3	−2.4	+0.5	−0.7	−1.7	+0.2	−0.3	+0.9	+0.1	+0.5	−0.4
North Pacific	0.0	+0.2	+0.1	−0.7	+1.6	−0.1	−0.2	+1.3	0.0	−0.6	+0.6	+0.2	+0.2
Middle Pacific	+1.7	+0.6	−1.7	−1.1	−1.1	−0.3	+0.6	+0.9	+1.3	+0.8	+1.7	+0.6	+0.3
South Pacific	+1.5	+1.0	−1.6	−1.4	−1.6	−1.1	−0.4	−0.4	+0.7	−1.4	+1.7	+0.9	−0.2

LAMARCK AS METEOROLOGIST.

The most original and eminent of French naturalists, Jean de Lamarck (born 1744, died 1829) devoted himself in early life to the study of the atmosphere. In 1776 he published a paper "On Atmospheric Vapors."

A letter of reminiscences by his son William, written in 1865 is published in Science[1] from which we quote the following:

My father loved to penetrate untrodden fields, he avoided paths too clearly marked out; for him accident was a word empty of meaning; he believed that in Nature all things were subject to laws as certain as mathematics; but to discover them one must observe the facts, make comparisons, and admit only the explanation which was in concord with all the facts observed. The study of meteorology attracted his attention; he gave himself up to it with the more zeal, since it was a science still in its infancy; a science, as he loved them. For a long time people had, indeed, carried out meteorological observations, but these observations no one had been willing to study or to draw from them deductions. My father wished to undertake this task.

There was then in the Ministry of the Interior an intelligent man, a distinguished scientist, Chaptal, who approved the project of my father. He created for him an office in his ministry, and furnished him with correspondents at different points thruout the country. My father wished to keep the public in touch with the progress which he would have made in the study undertaken by him, and to this end published a meteorological yearbook in which he had the unfortunate idea of including both memoirs purely scientific and probabilities of the weather to come. This was intended to help along the sale of the work, but it furnished also a weapon for his critics. The astronomers of the Bureau of Longitude, furious to see a naturalist exploit a field which they believed belonged to them, hastened to avail themselves of this weapon; they transformed "probabilities" into "predictions," and upon this ground they made a great outcry. A member of the Institute to play the part of a Mathieu Lansberg! * * * They petitioned the emperor [Napoleon] to cause such a scandal to be stopt. The emperor was a member of the Institute and this was not one of the titles of which he was least proud. At a public reception he apostrophized my father sharply on this subject and concluded by telling him that botany should be kept within its proper bounds. ("La botanique! A la bonne heure.") From that time the ministry deprived my father of his office and his correspondents and stopt the publication of the meteorological yearbook. Thus it was that the reprimand of a sovereign before whom the entire world trembled, succeeded in placing outside of the scientific pale an old man who petitioned no one, who lived retired, and who sought for nothing but the advancement of human knowledge.

GEORGE W. HOUGH. 1836—1909.

By Prof. HENRY CREW. Dated Evanston, Ill., January 20, 1909.

On New Year's Day of the current year, 1909, the science of meteorology sustained a distinct loss by the death of Prof. George W. Hough, who more than a generation ago devised some very clever self-recording instruments, and who for full twenty years had given a course in meteorology and astronomy at Northwestern University.

George Washington Hough was born at Scribes Hill, Montgomery County, New York, on the 24th of October, 1836; graduated B. A. from Union College in 1856; married in 1870, and died at his home in Evanston, Ill., on the first day of the current year (1909).

Upon leaving college Professor Hough taught for a year or so in the schools of Dubuque, Iowa, and afterward he pursued graduate work in Harvard College; so that his serious astronomical work did not begin until 1859, when he accepted appointment as assistant astronomer in the Cincinnati Observatory, then justly celebrated on account of its powerful glass and its eloquent director, Gen. O. M. Mitchel.

At the end of his first year in Cincinnati came promotion to the directorship of the Dudley Observatory, Albany, N. Y., where he succeeded the late Dr. B. A. Gould.

His fourteen years of residence in Albany, 1860–1874, constitute a period during which his inventive genius was at its best. It was here that his printing barometer was brought out in 1865. This instrument gives two graphical records of the barometric height on different scales, and also prints with a type-wheel the reading of the barometer, at the end of each hour, to the nearest thousandth of an inch. It was about this time also that his self-recording thermometer and anemograph were devised. In the "Annals of the Dudley Observatory," vol. 2, Albany, 1871, may be found a description of these instruments, together with a continuous hourly record from the printing barograph for a period of five years. In 1871 he perfected his now well-known printing chronograph for recording very minute intervals of time.

An interval of five years, between 1874 and 1879, was devoted to commercial pursuits.

The latter of these dates marks his appointment as the successor of Prof. T. H. Safford, to the directorship of the Dearborn Observatory at Chicago, a post which he was destined to honor for the succeeding thirty years. The year 1879 also marks the beginning of his micrometric study of the surface of the planet Jupiter, which within a few years made him a leading authority on this subject.

His work on double stars, of which he discovered no less than 648, had its beginning in 1881. The difficulty and importance of many of these objects, as well as the observational skill which he brought to bear upon them, amply justify the rare compliment which Prof. Eric Doolittle—himself an observer of high rank—has recently paid to Professor Hough, by remeasuring the entire list of his 648 stars.

Only one binary, "δ Equulei" of Otto Struve, is known to be more rapid than Professor Hough's No. 212—"13 Ceti."—which has a period of seven years.

In 1888 the Dearborn Observatory was removed from Chicago to Evanston; a new dome was to be designed. That fine mechanical sense which had already enabled him to do much for the instrumental side of his science, now led Professor Hough to invent a roller-bearing dome and a most excellent observing chair which have been copied in many important observatories.

Professor Hough never considered class-room teaching as his chief function. Yet no student ever left his lecture with the recollection of an unkind word or of an explanation that was not clear.

Sham and ostentation were foreign to his nature. In simplicity of life, accuracy of scholarship, singleness of purpose, and kindliness of heart, his friends will all remember him as a worthy example.

[1] Science, January 24, 1908, 27:151–2.

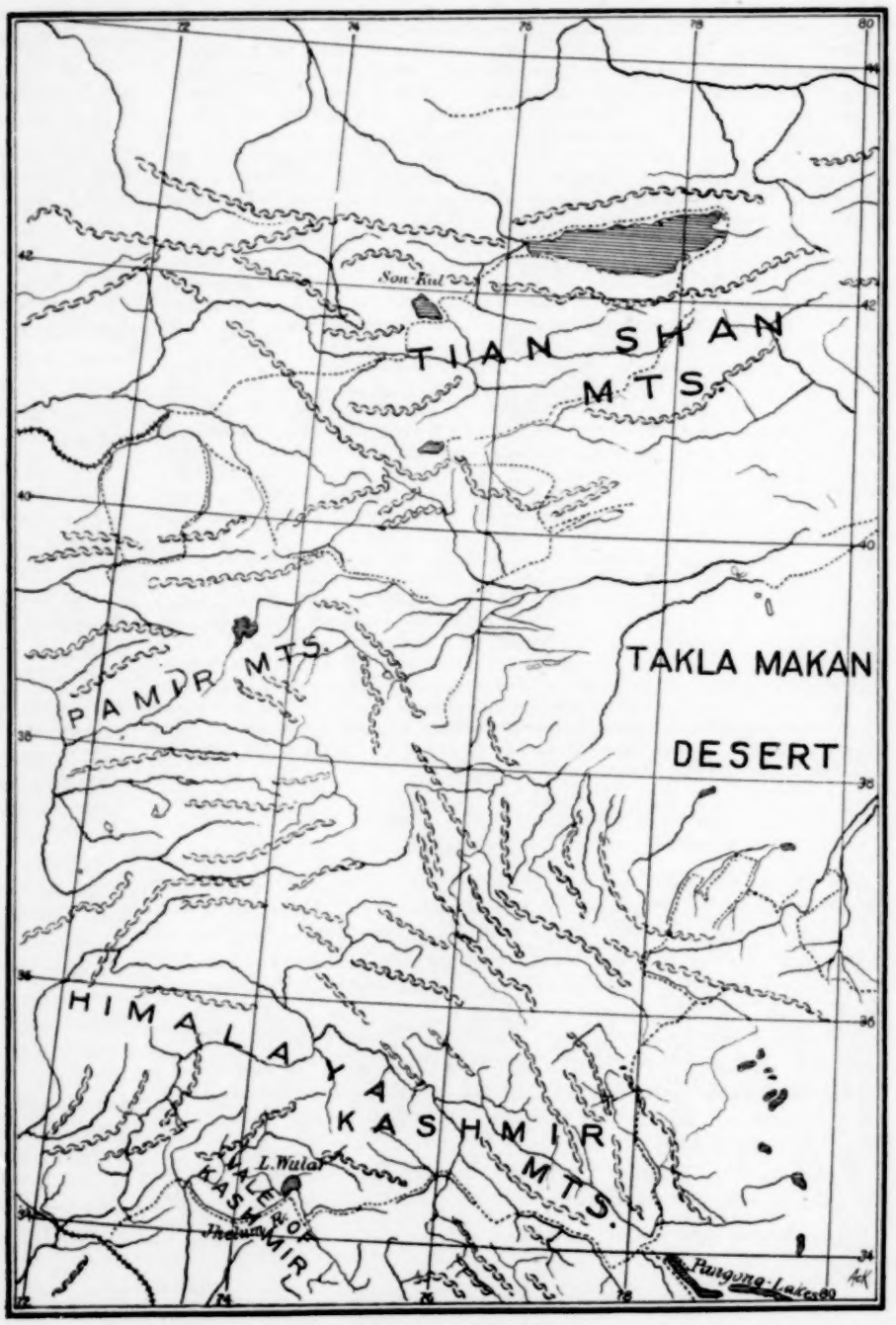


FIG. 1.—The deserts and lakes of central Asia. (See p. 449.)

..... Routes followed by Ellsworth Huntington.

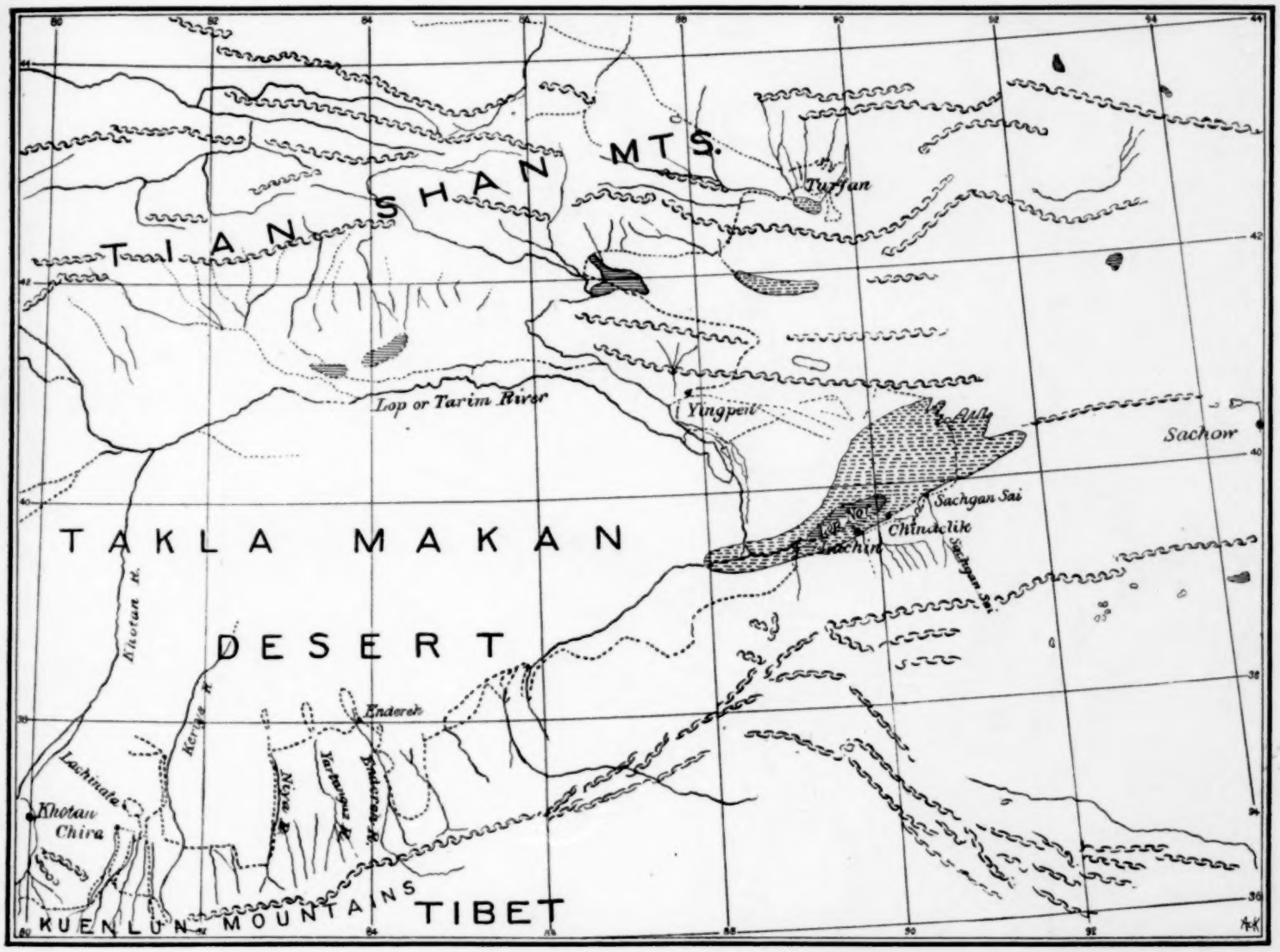


FIG. 2.—The deserts and lakes of central Asia. (See p. 449.)

..... Routes followed by Ellsworth Huntington.

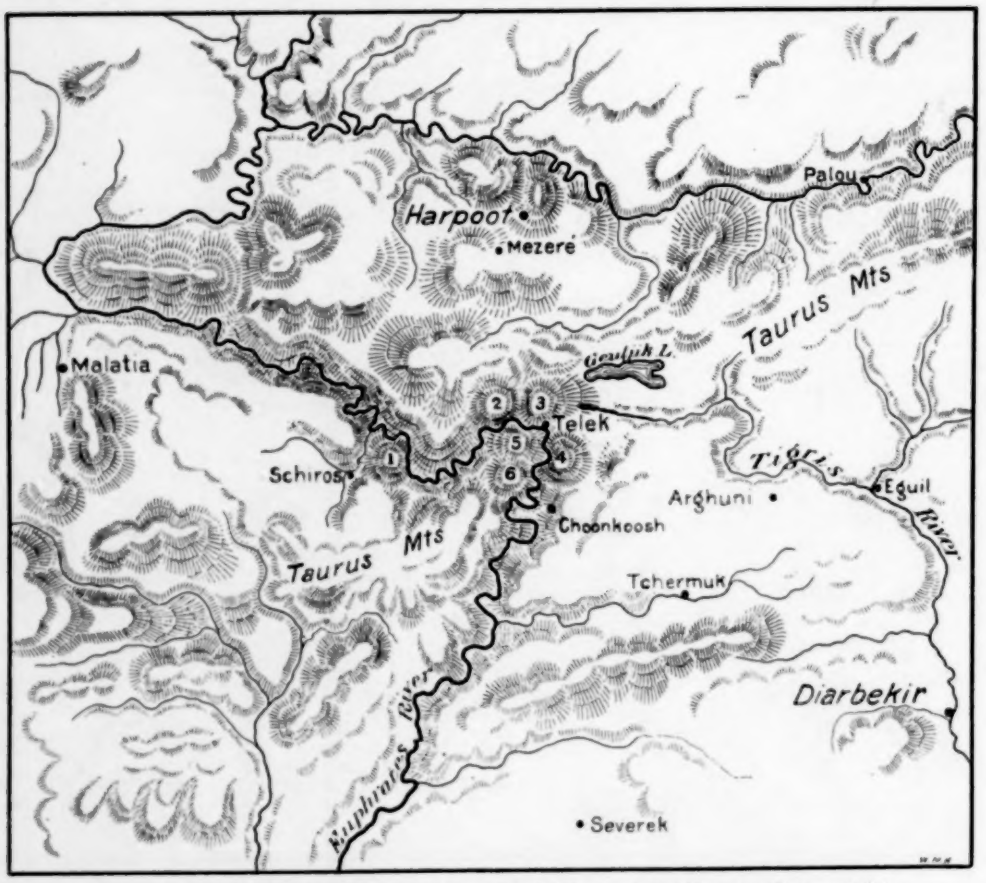


FIG. 3.—Location of Lake Geuljik, or Gyul-jük, in Asia Minor. (See p. 449.)

• Barkerville

Chart IV. Total Precipitation for 1908.

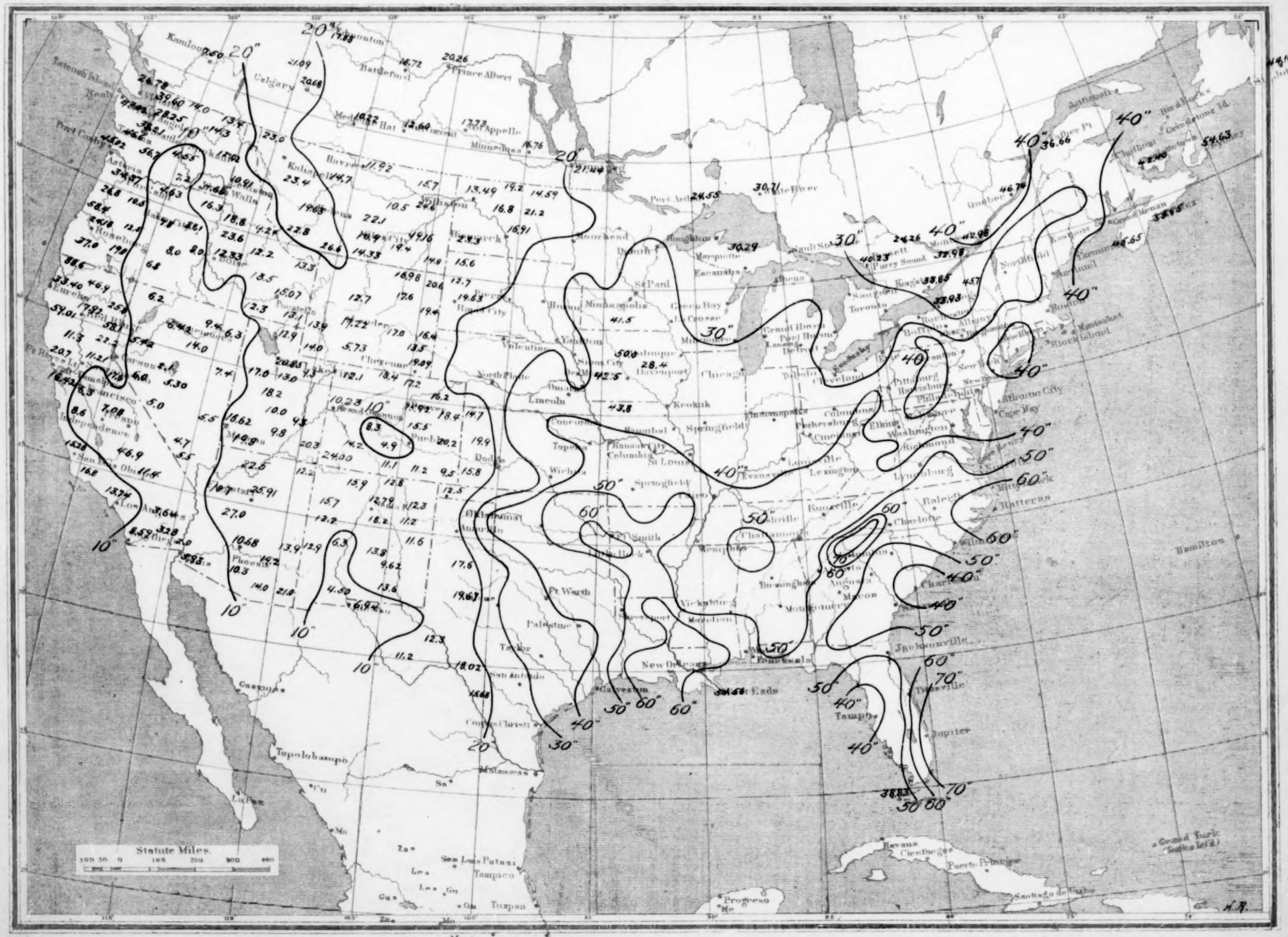


Chart V. Percentage of Clear Sky Between Sunrise and Sunset, for 1908.

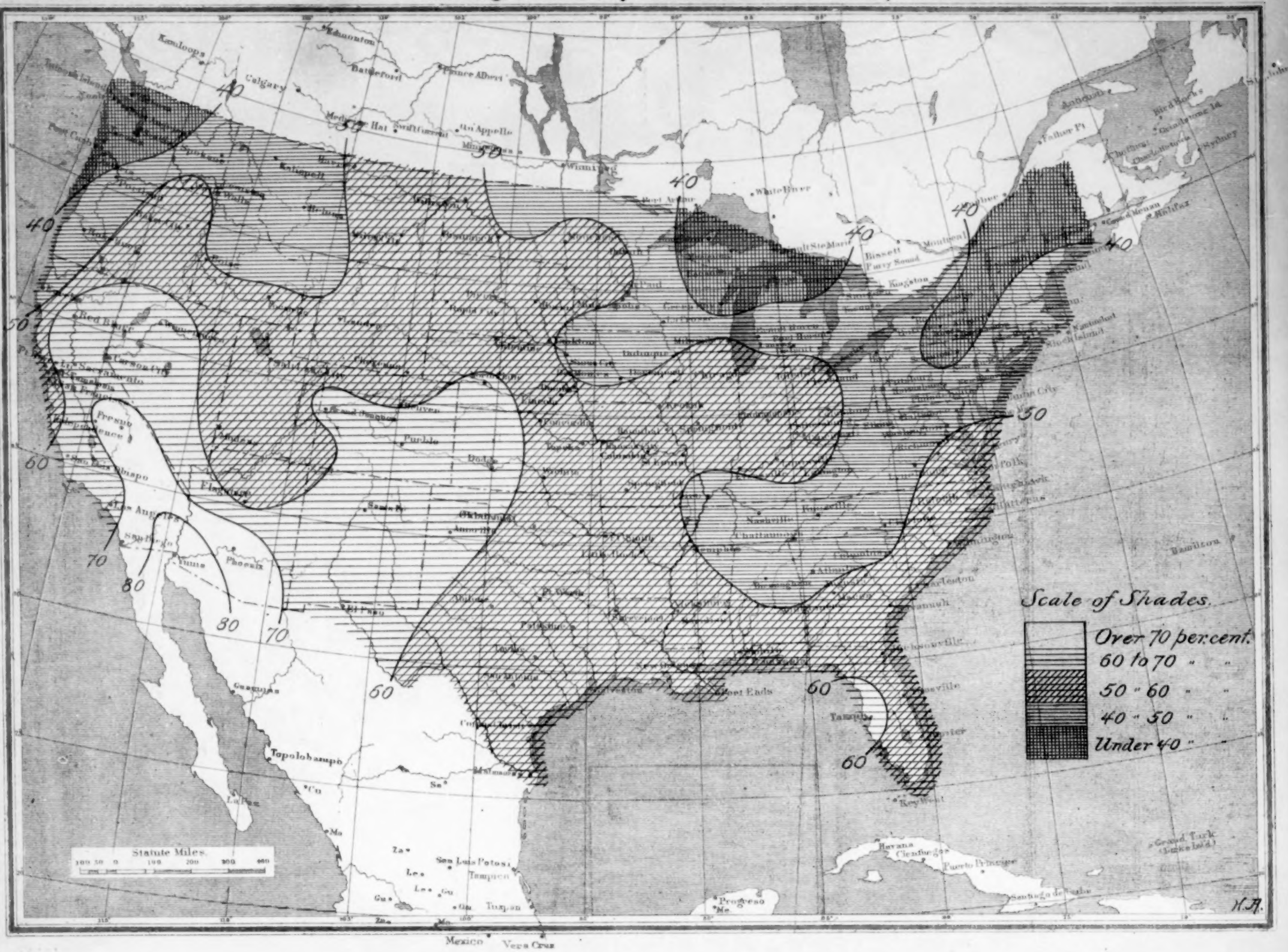


Chart VI. Isobars and Isotherms at Sea Level; Prevailing Winds for 1908.

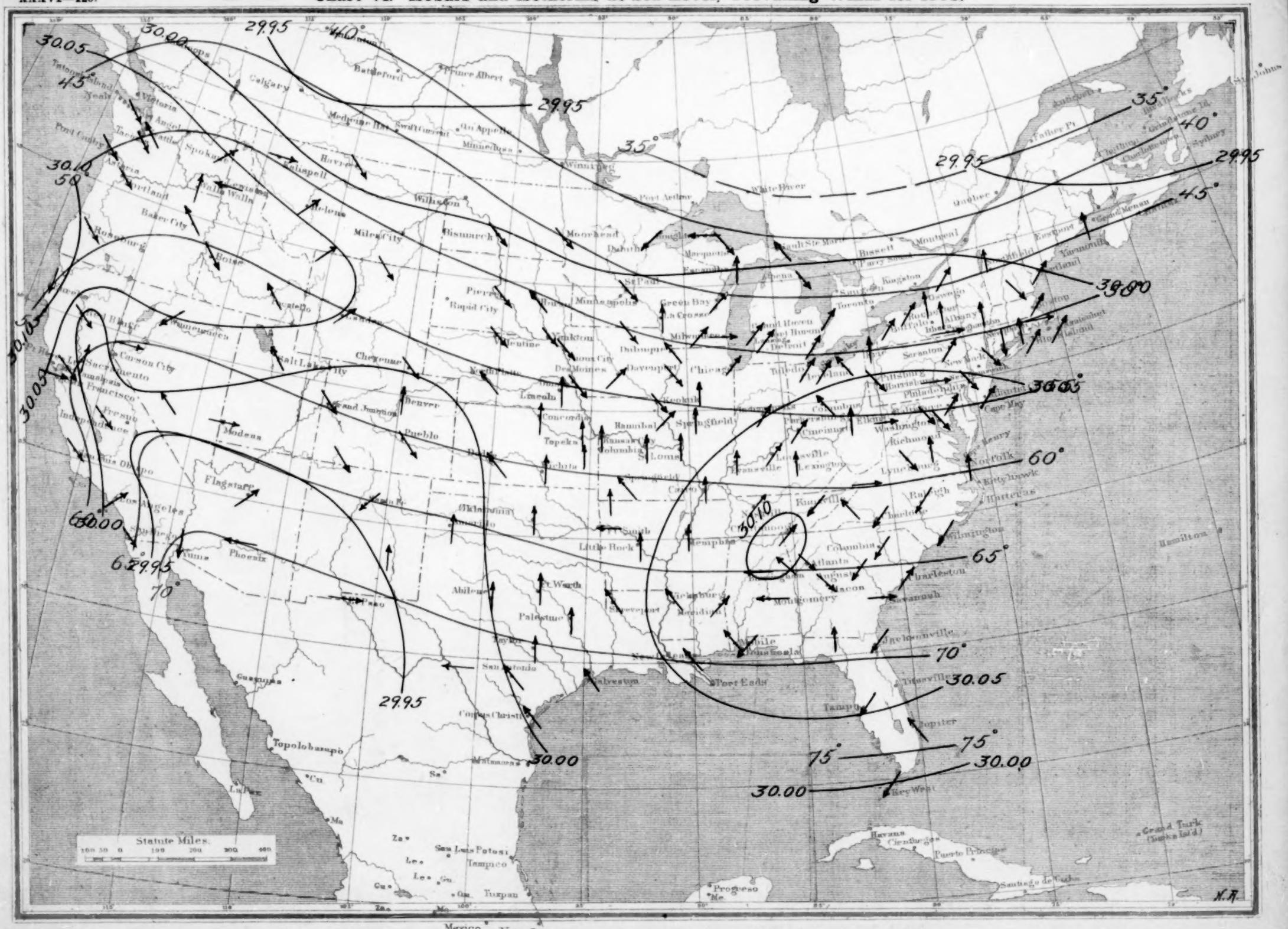
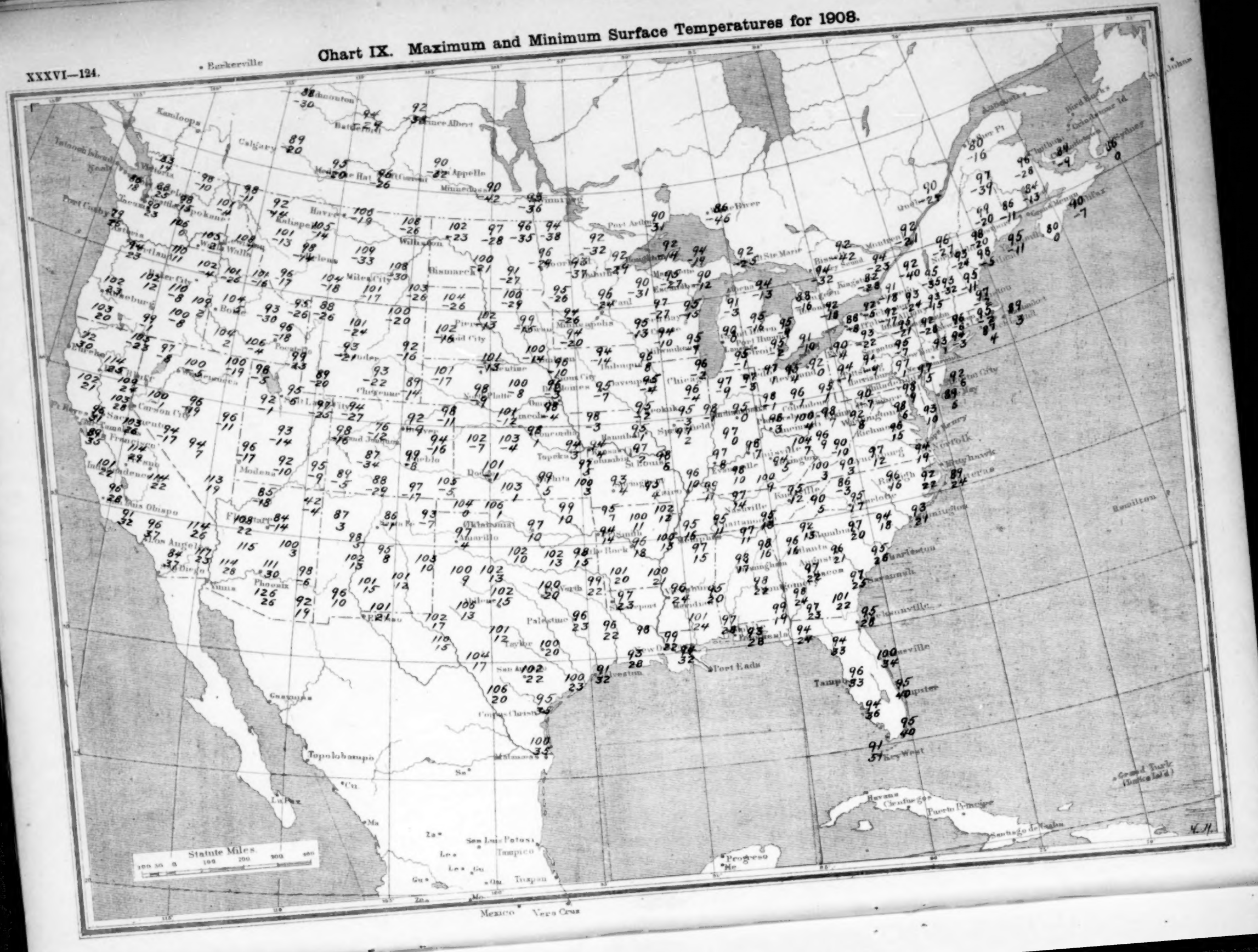


Chart IX. Maximum and Minimum Surface Temperatures for 1908.



Data for 1908

Chart X. Total Number of Thunderstorm Days for 1908.

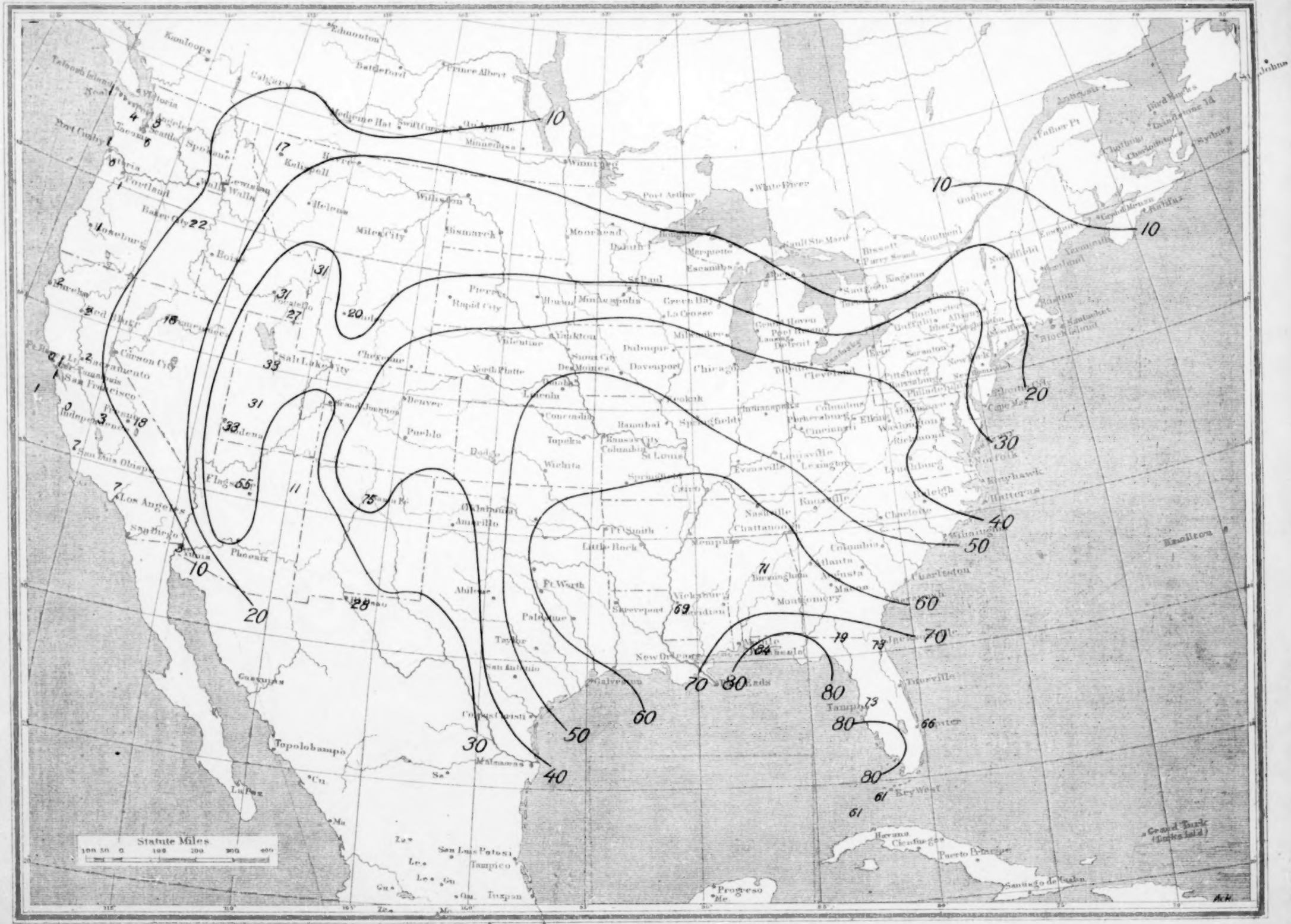
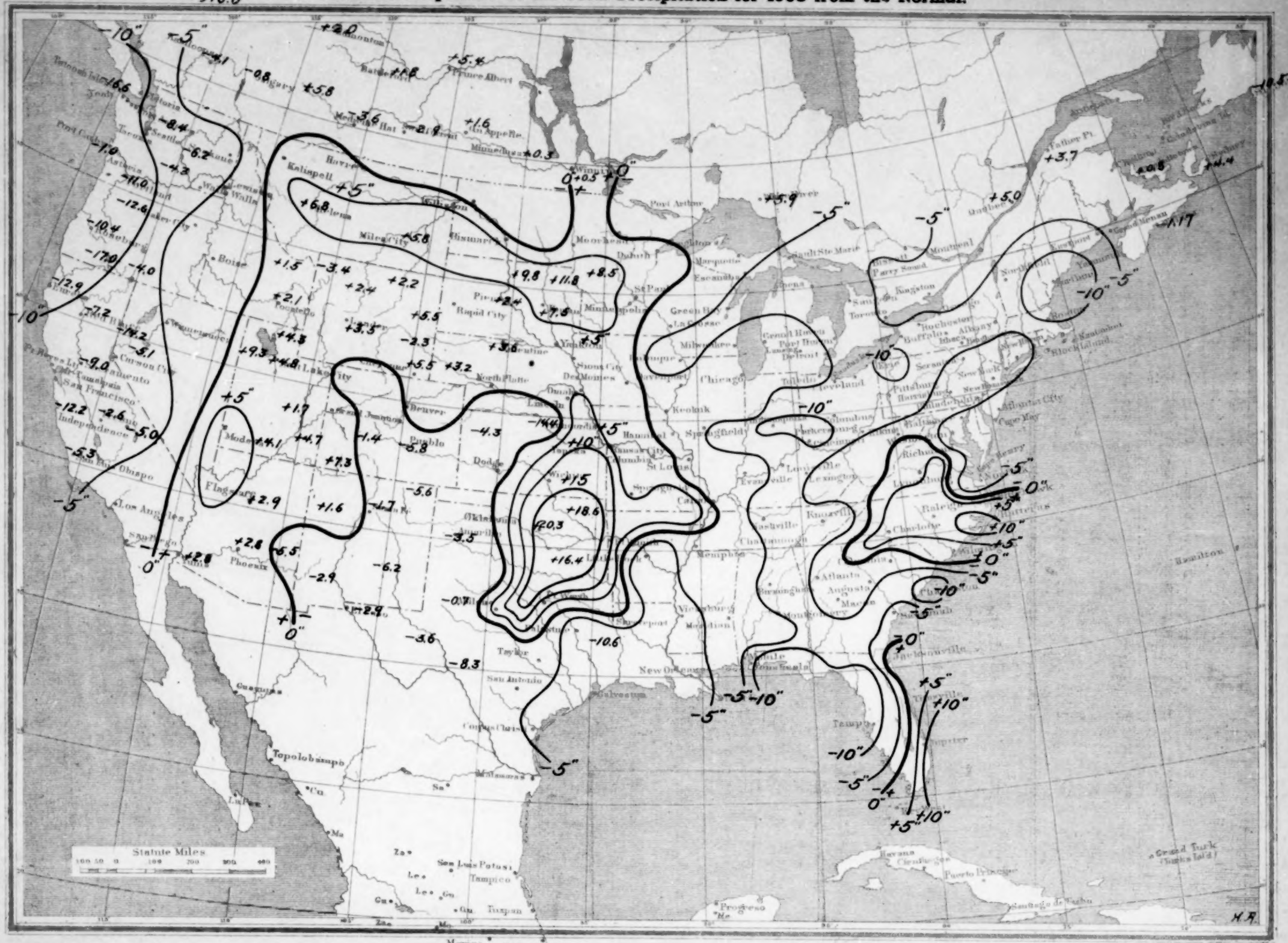


Chart XI. Departure of the Total Precipitation for 1908 from the Normal.



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